HANDBOOK
OF
FOREST PROTECTION

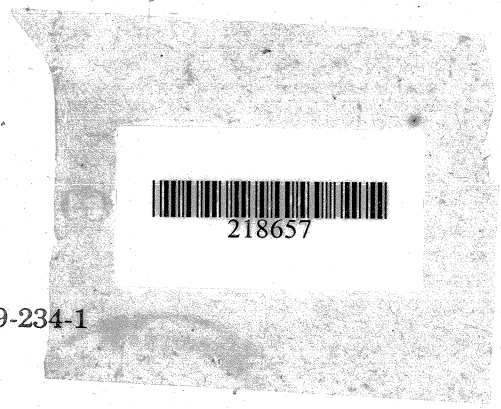
by

Dr. S.S. NEGI

INTERNATIONAL BOOK DISTRIBUTORS
9/3, RAJPUR ROAD, DEHRA DUN - 248001
INDIA

Published by :

International Book Distributors
9/3, Rajpur Road, Dehra Dun India



ISBN : 81-7089-234-1

Type setting by :

TypeStyler DTP & Co. ..er System, Dehra Dun

Published by R.P. Singh Gahlot for International Book Distributors, Dehra Dun and Printed by Prashant Gahlot at Valley Offset Printers and Publishers, 15/2-B, Rajpur Road Near Akash Club, Dehra Dun.

PREFACE

Forest protection is one of the most important functions performed by foresters not only in India, but also in other parts of the world. Today, forests are adversely afffected by climatic, human and other biological agencies. The subject matter of forest protection covers protective measures against these agencies. It includes both preventive and remedial measures.

This publication is a text book on forest protection covering the prescribed syllabus for IFS/SFS/Rangers' training courses and M.Sc./B.Sc. Forestry degree classes. it includes protection of forests from adverse climatic factors, human beings, animals, plants, diseases and insect pests. The causes and preventive and remedial measures with respect to different adverse influences have been discussed in detail.

The author is indebted to his friends and colleagues for their good wishes and encouragement. Thanks are also due to my wife, Manju, for her self denial and to the publishers for publishing this book in a short time.

Dr. S.S. NEGI
24, SUBHASH ROAD
DEHRA DUN

39-781, 110 - 200

CONTENTS

CHAPTER 1

INTRODUCTION

In broad terms protection pertains to shelter or shield against the dangers or damages that may otherwise be caused to that which is being afforded protection. Forest protection pertains to activities or actions directed towards the prevention and control of damage to trees, forests and the entire forest ecosystem by human beings and his activities, animals (both wild and domestic), insects, diseases, plants and adverse climatic conditions.

This is a very specialised field of forestry which requires knowledge of many other disciplines, branches and subjects such as silviculture, legislation, extension, entomology, pathology, botany, meteorology, wildlife management etc.

In India forest officers are required to protect the forests under their charge be it at the beat, block, range, division or circle level. Most of the 641 thousand sq.km of forests in our country are owned by the state and have to be protected directly or indirectly by the forest department manned at various level by trained foresters. The value of these forests may be several thousand crore rupees if we take into account only the cost of the timber growing in them though the ecological value of these forests is much more. Thus an adequate knowledge of forest protection is essential for all forest officials.

BENEFITS OF FORESTS

Forests are very important and beneficial for the overall well being of not only the people of a region or country but of the entire human race. The wood consumption of a nation is being used to measure its economic prosperity. The higher the per capita consumption of wood in a country, the more advanced and well developed it is taken to be.

The direct economic benefits and indirect ecosystem benefits of forests are listed below:

(1) Source of energy

(2) Fodder, food , fruit and fibre.

(3) Source of employment

(4) Raw material for large, medium and small scale and local cottage industries

(5) Amelioration of climatic conditions

(6) Soil and moisture conservation

(7) Flood control

(8) Aesthetic and recreational role

(9) Improving the ecosystem

(10) Controlling environmental pollution

(11) Habitat for wild animals

BRIEF HISTORY OF FOREST PROTECTION

Little is known about the forests of ancient India. Scientific evidence confirms that most of the country was covered by dense forests when the Dravadian culture and civilisation flourished as long ago as 2000BC. The people lived in perfect harmony with forests that were abundant. They depended on forests for their food both in the form of fruits of trees and the meat of the wild animals living in the forests.

There seems no reason to doubt that in the very early part of India's history most of the country was covered with more or less dense forests that were inhabited by aboriginal tribes.

The early Aryans were a pastoral people, interested in the pursuance of agriculture. They cleared forests only in the areas in which they actually settled and maintained all their religious and educational institutions in the sylvan surroundings of the forest. Attractive descriptions of forests like the Dandakaranya, Nandanvan and Khandavan are available in the Ramayana and Mahabharata There was great reverence for forests near temples. Even at the time of the invasion of Alexander in 327 BC much of the country was covered by dense forests.

In 300 BC Chandragupta Maurya realised the importance of forests and appointed a high official to look after the forests of his kingdom. Punishments were prescribed by him for specific forest offences. Forest protection assumed great importance during the rule of Ashoka. He advocated that wild animals and trees must be protected. Stress was laid on the planting of trees along roads, paths and camping sites. The famous edicts of Ashoka also cover tree planting and protection of forests and wild animals.

With the Mughal invasion the local people who were uprooted sought refuge in the forest which they cleared for settling down. The invaders had scant regard for forest conservation and protection. With the fall of the Mughal empire the country was once again divided into small kingdoms leading to wars as a result of which the displaced people moved into remote forest areas which were cleared. This period saw the widespread destruction of forests in India. In the mountainous parts of central, southern and eastern India the practice of shifting cultivation was widely adopted leading to widespread deforestation. Little or no attention was paid to forest protection and conservation except in some kingdoms.

In the early British period sacred groves and game preserves were found in many princely states. In south India such protected forest areas included the Devara Kadus or sacred groves of Coorg; the Swami shola on the Yelagiris; the sacred groves at Pudus on the Javadis and several sacred forests on the Shevaroys. In the dry parts of Rajasthan and adjoining tracts

sacred groves were set aside for conservation and protection in Banswara, Pratapgarh , Mewar and other areas.

Protected woodlands known as Khans were maintained in the moister parts of Mysore state. These were patches of evergreen and semi-evergreen forests found along the western ghats. Adequate fire protection measures were taken in these tracts by laying out firelines.

However in British period there was heavy exploitation of the forest wealth of India with little regard for protection and conservation. The arrival of Brandis as the first Inspector General of Forests saw the advent of scientific management with some attention towards protection and conservation of forests.

After 1878 with the setting up of research and training facilities at Dehradun specialised fields such as forest pathology and entomology pertaining to Indian forests were developed and the knowledge generated applied to the field. Forest protection came to be taught as a separate subject and forest officials attained a fair degree of proficiency in these fields.

GENERAL OUTLINE OF FOREST PROTECTION

Constraints for forest protection:

It is a well accepted fact that adequate protection must be accorded to our forests for their conservation and well being of the human race. Forest protection in India is affected by the following constraints:

(1) **Vast extent of forests** : The forest area to be protected is very vast in extent. As a result it is difficult to protect the forests from the the ever increasing biotic pressure.

(2) **High costs** : Forest protection is usually fairly costly and often funds needed may not be available.

(3) **Rights and concessions** : People living in and around forest areas enjoy rights and concessions in forests with respect to a number of forest products and pasture of their cattle. This allows the right of entry into forests which leads to the problems of illicit fellings, forest fires and other forms of damage to the forests. The rights and concessions may also be misused.

(4) **Lack of awareness** : There is a general lack of awareness amongst the people living in the vicinity of forests about -

- the seemingly inexhaustible resources available in the forest.
- the role played by forests in our everyday lives particularly with respect to food and ecological security.
- the need to protect and conserve forests.
- the magnitude of the damage that their actions may cause to the forest ecosystem on a long term basis.

Moreover till about a few years back the local people were not usually involved in forest protection due to which they did not have a feeling of involvement in these programmes.

Types of protection measures:

Forest protection measures may be classed into the following:

1. Preventive measures:

This class of measures prevent the occurrence of damage to forests. They include -

- legal safeguards for prevention of damage
- creation of public awareness
- putting up signs and posters
- earning the goodwill and cooperation of the local people in forest protection
- measures such as laying out fire lines and control burning
- patrolling by the forest staff
- general vigilance against forest offences
- sanitation measures

2. **Remedial measures :**

This class of measures include steps taken after the occurrence of damage. They also include measures for controlling the damage and also rehabilitation of the affected area. They include the following-

- putting out fires once they have broken out.
- controlling the outbreak of an insect or disease attack on the trees in a forest.
- rehabilitation of damaged areas

FENCES

Fences are an important protective measure taken for keeping out human beings and various types of animals from a forest or forest nursery. The following types of fences are usually used in forestry in India.

1. **Live fence :**

This type of fence consists of rows of living plants or trees raised on the boundary of a forest plantation or nursery. It includes hedges. The species that may be used for live fences are : *Agave sisalana, Acacia, Cassia, Euphorbia, Ipomea, Jatropha, Opuntia , Prosopis* and *Vitex.*

2. **Thorn fence :**

This is a fence made by heaping thorns bushes such as *Zizyphus*. It may be reinforced by erecting posts at regular intervals.

3. **Brushwood fence :**

This fence is made up of a series of poles or posts with brushwood woven horizontally to make a continuous fence. This fence is able to keep out smaller cattle and human beings.

4. **Stone wall fence:**

This is a continuous wall made of stones where poles are scarce and the availability of stones is relatively easier. No cementing material is used in these walls. It is able to keep out cattle and human beings.

5. **Barbed wire fence:**

This fence is made of barbed wire that is strung horizontally across wooden or angle iron posts or poles at regular intervals. Barbed wire fences are commonly used as a forest protection measure in India. Three types of barbed wire fences are commonly erected.

(a) Simple barbed wire fence:These are made of simple barbed wire strands (4 or 5) strung across wooden or angle iron posts. The purpose is to keep out cattle and human beings from the protected forest or nursery. The distance

between two posts is 4 or 5 mts. and the spacing between two strands of the barbed wire may be 20 to 30 cms.

Small gates or revolving stiles may have to be provided at regular intervals for the entry of forest staff.

(b) Game or deer and antelope fence: The purpose of this barbed wire fence is to prevent the entry of deers and antelopes. It is a modification of the simple barbed wire fence and consists of the following:

- fence posts of wood or angle iron having a height of about 2.5 mts above the ground
- 6 to 7 strands of barbed wire at a spacing of about 10 to 20 cms
- cross strands of barbed wire

(c) Porcupine fence:This is a type of barbed wire that prevents the entry of porcupines and wild boar into an area. It consists of the following:

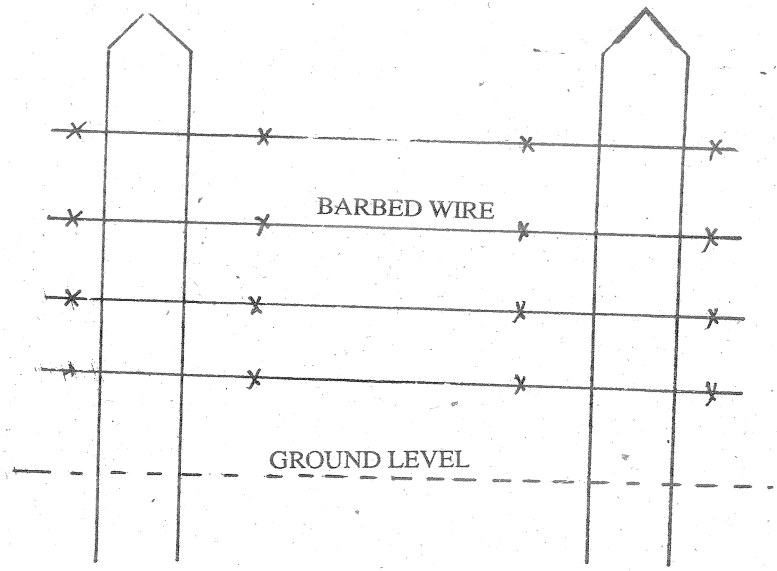
- a wire mesh dug into the ground
- fence posts of wood or angle iron
- 3 or 4 strands of barbed wire fixed between these poles above the ground

TRENCHES

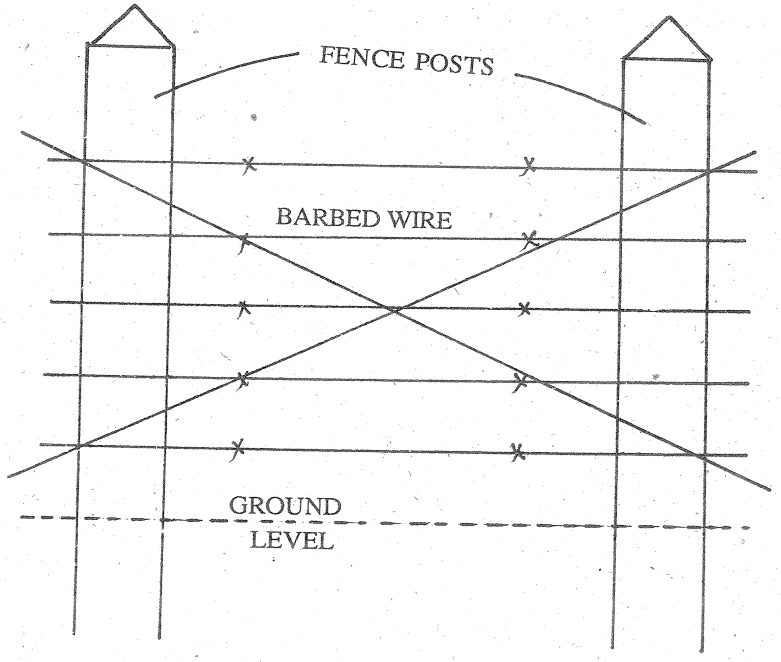
Fences may not be able to keep big wild animals such as elephant and rhinoceros out of an area. For this trences have to be dug. Their specifications are:

- width 4 to5 mts.
- depth 3 to 4 mts
- side slopes vertical

The trenches are sown with thorny species or even filled with water where it is available in plenty.



SIMPLE BARBED WIRE FENCE



DEER AND ANTELOPE FENCE

CHAPTER 2

FOREST POLICIES AND PROTECTION

Ever since forest management started in India more than 125 years back the state has had a forest policy which saw changes from time to time keeping in view the changing conditions. This chapter deals with the various provisions that were made in the forest policies over the years with regard to forest protection.

CHARTER OF INDIAN FORESTRY 1855

Amongst other interesting suggestions this charte. also made observations with respect to imposing restrictions on the unchecked exploitation of forests by private parties.

FOREST POLICY OF 1894

This was the first regular forest policy of India. Amongst the four broad categories of forests outlined in this policy the first covered forests whose preservation was essential on climatic or physical grounds.

The policy stated that these forests are generally situated on hill slopes where the preservation of such vegetation as exists, or encouragement of further growth, is essential to the protection from the devastating action of hill torrents on cultivated plains that lie below them. Here the interests to be protected are important beyond all comparison with the interests which it may be necessary to restrict; and so long there is a reasonable hope of the restriction being effectual, the lesser interests must not be allowed to stand in the way.

NATIONAL FOREST POLICY, 1952

This was the first policy of independent India formulated in the year 1952 soon after the country became independent to serve as a vehicle for the aspirations of millions of Indians.

Amongst the six vital national needs outlined in this policy were-The need for checking:

- denudation in mountainous regions, on which depends the perennial water supply of the river systems whose basins constitute the fertile core of the country.

- the progress of erosion along the treeless banks of the rivers leading to the formation of ravines and on vast stretches of undulating wastelands depriving the adjoining fields of their fertility.

- the invasion of sea sands on coastal tracts and the shifting of sand dunes particularly in the Rajasthan desert.

Amongst the functional classification of forests are protected forests which must be preserved or created for physical and climatic considerations.

This policy realised that the indiscriminate extension of agriculture and consequent destruction of forests have not only deprived the local population of fuel and timber, but have also stripped the land of its natural defences against dust storms, hot desiccating sands and erosion. It stated that the notion that forestry as such has on intrinsic right to land but may be permitted on sufferance on residual land not required for any other purpose. The role of forests in the national economy entitles forests to lay claim to an adequate share of the land. The importance of treelands in the rural economy of this region where agriculture constitutes the mainstay of the vast bulk of the population can scarcely be over-emphasised.

Protection forests were classed to include forests found or required on hill slopes, river banks, sea shores or other erodible localities. On such sites the need for a forest cover is dictated by purely protective physical considerations such as prevention of erosion, conservation of moisture and control of

rushing torrents and floods. The policy document states that the role of such forests in saving the soil from being washed away and when maintained in the catchment area in the prevention of floods and maintenance of stream flow cannot be over-emphasised. On flat country with loose sandy soil, especially under dry conditions, forests whether natural or artificial perform an essential function in minimising wind erosion, fixing the soil and preventing the formation of sand dunes and mitigating the desiccation of agricultural crops leeward of the tree cover.

The policy stated that the primary object of management of such forests should be utilised in full, their protective influence on the soil, water regime, and the physical and climatic factors of the locality; and the interests to be thus protected should far outweigh those which it may be necessary to restrict.

Another important point dealt with in this chapter is the proportion of land to be kept permanently under tree cover. For obvious reasons, this would differ from region to region. It stated that practical considerations suggest that India as a whole should aim at manipulating one-third of its total area under forests. As an insurance against denudation a much larger percentage of the land about 60 percent, should be kept under forests for their protective functions in the Himalayas, the Deccan and other mountainous tracts liable to erosion. In the plains where the ground is flat and erosion is normally not a serious factor, the proportion to be attained should be placed at 20 percent; and in view of the pressure on agriculture, effort at the extension of treelands should be concentrated on river banks and other convenient places not suitable for agriculture. At the same time it must be realised that even distribution of forests in all physical regions is as important as its overall proportion. In certain localities, deficient in forests therefore, afforestation of marginal lands and eroded river and village wastelands should be undertaken. Forest area in excess of the indicated proportion, if any should not be sacrificed. To maintain an overall average, it is essential that states better suited for the growth of trees should help to make good the deficiency in those parts where climatic and edaphic factors are against tree growth. This policy guideline

is very important from the point of view of preventing further deforestation in our country.

NATIONAL FOREST POLICY, 1988

Keeping in view the fast changing conditions in India and the over-all perception of forests, the need for a new forest policy was being felt. As a consequence, the national forest policy was formulated in 1988. This policy is more oriented towards conservation and protection as is evidenced from the major objectives most of which cover these aspects. They include the following objectives-

- maintenance of environmental stability through preservation and where necessary restoration of the ecological balance that has been adversely disturbed by serious depletion of forests of the country.

- conserving the natural heritage of the country by preserving the remaining natural forests with the vast variety of flora and fauna, which represents the remarkable biological diversity and genetic resources of the country.

- checking soil erosion and denudation in the catchment area of rivers, lakes, reservoirs in the interest of soil and water conservation for mitigating floods and droughts and for the retardation of siltation of reservoirs.

Important provisions of this policy with regard to forest protection and conservation are reproduced below:

(1) Diversion of forest land for any non-forest purpose should be subject to the most careful examinations by specialists from the point of view of social and environmental costs and benefits.

(2) While safeguarding the customary rights and interests of tribal people forestry programmes should pay special attention to -

- protection, regeneration and optimum collection of minor forest produce

- undertaking integrated area development programmes to meet the needs of the tribal economy in and around the forest areas including the provision of alternative sources of domestic energy on a subsidised basis to reduce pressure on the existing forest areas.

(3) Encroachment on forest land has been on the increase. This trend has to be arrested and effective action taken to prevent its continuance. There should be no regularisation of existing encroachments.

(4) The incidence of forest fires in the country is high. Standing trees and fodder are destroyed on a large scale and natural regeneration annihilated by such fires. Special precautions should be adopted to deal with forest fires.

(5) Grazing in forest areas should be regulated with the involvement of the community. Special conservation areas, young plantations and regeneration areas should be fully protected. Grazing and browsing in forest areas need to be controlled. Adequate grazing fees should be levied to discourage people in forest areas from maintaining large herds of non-essential livestock.

CHAPTER 3

FOREST BOUNDARIES

One of the most important measures for the protection of a forest is a clearly defined boundary and permanent demarcation. This protects the forest against fraud and damage and affords security for all aspects of forest management. Forest boundaries are a specialised field the knowledge of which helps the forester to protect the forests from the various activities of human beings that tend to have adverse effects on trees and forests.

KINDS OF FOREST BOUNDARIES

There are two broad types of forest boundaries in use in India. These have been described below:

1. **Property boundary**:

Property boundaries separate forests or their parts from other lands. These may be external or internal boundaries depending on the portion of the forest enclosed by them.

2. **Administrative boundary**:

These boundaries define administrative or working units of forests such as beat, block, range or divisional boundaries;or compartments, periodic blocks, working circles and working sections.

SETTLEMENT OF BOUNDARIES

It is important to properly demarcate and carry out the settlement of all forest boundaries. The procedure adopted for settling boundaries differs on the kind of boundary such as property or administrative boundary. Administrative boundaries depend on the owner which in most cases in India is the forest

department while property boundaries define the exact limit of the forest property. Thus the latter must be very accurate and this is of utmost importance to both the forest department which is the custodian of the forest on behalf of the state and to the owners of the adjoining forests.

Usually the procedure for settlement of forest boundaries is laid down by law. Evidence with regard to the correct boundary consists of existing boundary pillars, natural features, roads, traces of the boundary or boundary maps. The settlement is best done by a public surveyor who may be chosen by the parties concerned or by the executive state or local authority as prescribed by law.

During the process of settlement of forest boundaries the representative of the forest department, usually the block officer, an official of the revenue department and the owner of the adjoining land must be present. As far as possible the location of the boundary must be settled with mutual consent between the forest department and the owner of the adjoining lands.

Once the boundary points have been finally settled they must be marked in any one of the following ways-

- by durable posts
- by digging narrow trenches in the direction of the boundary lines
- by forming a circle around each line.

DEMARCATION OF BOUNDARIES

Boundaries are demarcated or permanently marked with the help of natural, artificial or mixed features. It is more essential to mark property boundaries permanently than administrative boundaries.

1. Natural boundaries:

Natural boundaries are used for demarcating forests. These include the following:

(a) Water divide

(b) Water courses and water bodies

(c) Ridges

(d) Peaks and passes

(e) Specific trees that have been marked

Amongst these water courses, water bodies and trees are not very permanent as the courses of rivers and streams tends to change. Marked trees may be uprooted in storms or could be felled by unscrouplus elements. In the case of water courses, mid-stream is generally taken as the boundary. Very often boundary pillars may be marked along water courses so that even if the river or stream changes its course the pillars show the location of the boundary.

2. Artificial boundaries:

These are man made features showing the boundary of a forest or property. The following types of artificial boundaries are used in Indian forestry :

a. Roads:

Metalled or unmetalled roads may be used for showing the boundary of a forest or its part. However there may be an objection to a road as a boundary as the alignment may require the road to be curved whereas the actual boundary may not be so.

Nevertheless, a well aligned road forms an excellent and economical forest boundary.

b. Boundary marks:

These are different types of boundary marks erected in a line at intervals so as to show the location of the boundary. The various boundary marks are-

- mounds of earth or stone
- wooden or iron posts
- boundary pillars made of masonry or cut stone blocks

All boundary marks should be numbered consecutively and the numbers painted on them in a way that they can be distinguished separately. The location of these boundary marks are shown on a map and also on a boundary pillar register maintained for the purpose. This gives the forward and backward bearing of the boundary marks so that they can be readily located in case of any discrepancy. Moreover if additional boundary marks have to be made their details too are recorded in these documents. The map and register is maintained at the range level.

i. **Mounds:**

Mounds of earth, stones or bricks are made for functioning as boundary marks usually as a temporary measure. As far as possible the mounds should be made of stone if these are readily available. The slope of the mounds will correspond to the natural angle of repose for the class of material that has been used and the height of the mounds must be atleast 1 mt. Earthen mounds must be carefully protected by placing sods on their surface.

ii. **Posts:**

Posts made of iron or wood may also be used as boundary marks. If the latter is being used, the post made of durable heartwood is first planted in the soil with the portion in the ground having being charred or the whole post creosoted or tarred in order to increase its life. The number of the boundary mark is painted on the post.

These posts are firmly placed in the ground in a way that they remain permanent and cannot be disturbed by miscreants.

iii. **Boundary pillars:**

These are the best boundary marks made from specially cut stones or masonry pillars. The former may be prismatic, triangular or rectangular in section with a rounded top on which the number of the pillar and also the alignment of the adjacent pillars are etched. The lower parts of such pillars are left rough so as to ensure their stability.

Boundary pillars may also be made of brick and mortar or rubble masonry with a good foundation. The number is engraved on a flat stone or slate and inserted in the sloping top of the pillar. Such boundary pillars may be cubical in the lower part having side upto 0.75 mts and a pyrimadical top 15 to 20 cms high.

In most parts of India, charcoal is buried beneath boundary pillars so that their location can be readily detected in case miscreants manage to destroy the upper part of the pillar.

c. **Rows of trees and Hedges:**

Rows of trees and hedges are also used for showing the external or internal boundaries of forests. These may either be independent boundary lines or may be used for supplementing a line of boundary marks.

d. **Fences and Walls:**

Fences and walls also form boundaries though their erection is very expensive and they are difficult to maintain. However fences and walls may be used as boundaries in areas prone to encroachments and to prevent the entry of human beings and animals into forests near human settlements.

MAINTENANCE AND IMPROVEMENT OF BOUNDARIES

Forest boundaries require frequent maintenance and improvement. As has already been mentioned in the previous text a detailed programme of maintenance is prescribed as a part of forest management. The main points to be kept in mind are:

(1) Periodic clearing of the boundary line so that one mark is visible from the adjacent one.

(2) Regular inspection of the boundary pillars by different levels of forest officials.

(3) Regular repairing of boundary marks

(4) A phased programme for changing temporary boundary marks into permanent ones.

CHAPTER 4

FOREST OFFENCES

Forest offences are usually dealt with under the subject matter of Forest Law which is a separate subject. However this topic has been briefly discussed here as forest offences also have a bearing on forest protection. Offences which affect or have an adverse effect on forests or that interfere with control are naturally sometimes of a kind that may occur with respect to any property and at times of a special character.

In India, forest offences are covered under the following main legislations:

(a) Indian Penal Code

(b) Indian Forest Act

(c) Wildlife Protection Act

(d) Forest Conservation Act

Some state governments have enacted legislation dealing with forest offences with regard to private lands such as felling of trees without permission of the forest department.

Broad Classification of Forest Offences:

Forest offences may be classed into the following broad classes:

1. **Damage:**

This pertains to the physical damage to the forest. Damage may further be of two types-

(a) **Unintentional damage** : this pertains to forest offences that take place unintentionally or unknowingly such as-

- damage to standing trees during felling operations or during removal of timber from the forest
- cutting up valuable timber into firewood
- cutting seedlings during grass cutting
- driving carts over boundary marks

(b) **Intentional damage** : also known as willful damage these offences are done willfully They include-

- peeling the bark from standing trees
- illicit felling of trees
- girdling trees
- cutting off leading shoots
- lopping branches or exposed shoots
- lopping branches from trees yielding fruit
- willful damage to boundary marks and fences
- damaging nurseries and plantations

2. **Misappropriation**:

This term includes the illegal appropriation of forest property. Simple misappropriation refers to any damage to the forest in a way that no loss of increment, no impoverishment of the soil results from the offence and there is loss of property illegally taken away. This includes-

- illegal removal of dead standing trees provided there is no damage done to the standing trees.
- removal of dead branches and trees damaged by wind and snow
- illegal removal of fruits not required for natural reproduction
- removal of stones on a large scale

On the other hand misappropriation accompanied by damage occurs when there is physical damage to the property in addition to the loss abstracted. This may differ in degree according to the circumstances e.g. species, age of the forest, system of management, density of growth and locality factors.

The different types of offences under this type of misappropriation are-

- cutting and removal of standing timber or parts of trees, involving loss of increment and irregularity of management, or introducing decay into the wood
- cutting green shoots from coppice stools
- removal of young plants from plantations
- peeling the bark of poles
- tapping for resin and gums
- lopping green branches for fuel
- raking up litter
- cutting sods

3. **Offences against forest control** :

These offences pertain to those which have been carried out in contravention of forest control regulations. These include-

- removal of wood at a time when it has been restricted to do so e.g. in the fire season

- using a closed road in a forest or entering a closed section of a forest

- collection of dead fallen wood without a permit, on forbidden days or with prohibited tools.

4. **Offences endangering the forest**:

These offences include-

- lighting a fire in the forest particularly during the fire season

- leaving unextinguished fires or throwing unextinguished cigarette butts, matches etc.

- carelessness in burning charcoal or lime

- entering a forest with torches

5. **Acts preparatory to a forest offence**:

These include acts preparatory to a forest offence such as-

- trespass into a forest

- carrying axes and saws into a forest

- injury to notices

PROTECTION AND CONTROL

There are many ways for protecting forests against offences and control of forest offences. These may be both direct and indirect measures. In the former efforts are directed

against the offence itself while the latter chiefly involves removal of the causes of the offence.

1. **Removal of cause of the offence** :

This includes the following measures-

(a) Optimum utilisation of all forest products so that the wants of the local population are met with as far as possible.

(b) Sale if possible at a low rate may be made of forest produce which is frequently misappropriated by the people

(c) Wherever possible, permits may be given without payment for removing non-timber forest products as far as consistent with the safety of the forest. These may be obtainable throughout the year.

Some examples are-

- grass cutting

- removal of fallen and dead fuel

- cutting of tall grasses

(d) Providing employment to the local people during the agricultural off season. This will help to instill a sense of involvement in forestry operations amongst the people.

(e) The forest department may provide, either free or at very low rates timber for schools and places of worship or where there has been widespread destruction due to fire. Fuelwood may be provided free of cost for fairs, community meals on special occasions and to burn the dead in

cases where there are no relatives of the deceased.

These measures help to generate goodwill of the local people towards the forest department.

(f) Exercising kindness and tact in dealing with the public. Their applications pending with the forest department may be disposed off speedily. This helps to prevent a feeling of hostility amongst the ignorant villagers.

However this does not imply that rules should not be followed while dealing with these cases.

(g) Providing all help to those people who come forward for planting trees.

2. **Direct dealing with forest offences:**

The following steps may be taken for directly dealing with forest offences:

(a) The forest area should be divided into suitable beats, blocks and ranges for effective patrolling against forest offences, trespassing or fire.

(b) Suitable action under the existing legislation should be taken as soon as a forest offence is detected.

(c) The local people should be involved in forest protection both directly and also through local bodies like panchayats. Nowadays village forest protection committees have been set up in many villages for helping the forest department in protecting forests.

(d) There must be regular monitoring of forest offences, their detection, identification of

offenders, confiscation of property, and also prosecution in court of law.

(e) Establishing check posts on important roads for keeping a check on the transit of forest produce.

(f) Setting up mobile squads for the detection of forest offences.

CHAPTER 5

DEFORESTATION

The removal of tree or forest cover from a particular land without the intention of reforesting it is termed as deforestation. During the past several centuries India lost much of its forest cover by way of deforestation and this process continued till about 1980 after which the rate of deforestation has slowed down considerably.

CAUSES

The main causes for deforestation have been discussed in the following text :

1. Clearing of forest land for agriculture

In the beginning human beings lived in the forests and when they began to take up settled agriculture small gaps were cleared for raising food crops. Gradually as the population grew the demand for land went up and more and more forest areas were cleared for agriculture. This continued unabated for several centuries and the forest cover shrunk drastically. Though the forest policy of 1952 stressed that no more forest land should be cleared for agriculture deforestation continued.

As a matter of fact most of the vast agricultural tracts of modern India were once thick forests. These include the plains of the Indus and Ganga rivers. This is one of the main reasons for deforestation in India. However after the adoption of the Forest Conservation Act of 1980 this has halted and now no more forests are being cleared for agriculture.

2. River valley projects

Hundreds of river valley multi-purpose projects have been taken up after and shortly before independence in various

parts of the country. These projects generate electricity, provide water for irrigation and prevent floods. The gigantic Bhakra dam was one of the largest such projects. However inspite of the immense benefits of the projects, they cause deforestation in the following ways-

- loss of forest land due to submergence under the reservoir
- loss of forest land due to construction of approach roads, housing colonies for staff and labour, godowns and other miscellaneous purposes
- loss of forest land for rehabilitating people displaced as a result of these projects.

Multi-purpose river valley projects have been the single major source of deforestation since independence and prime forest land has been lost as a result. In fact some of the rich virgin forests and ecosystems lost as a result can never be replenished.

Some years back these was a proposal to construct a river valley project in the Silent valley area of Kerala which would have submerged rare rain forests. However the hue and cry that was raised by the public at that time marked a watershed in the diversion of forest land for river valley projects. The government cancelled the plan for this project and from then on environmental clearance of all such projects was made mandatory. Now the rate of loss of forest land to these projects has slowed down considerably and where forest land has to be submerged, there is a provision for compensatory afforestation under which many times the area of the forest lost has to be afforested elsewhere through the forest department.

However the provision for compensatory afforestation has come in for criticism as environmentalists feel that the natural ecosystem lost cannot be created elsewhere particularly with respect to the biological diversity.

3. Settlements

Almost all human settlements of today including towns and cities were once forests. Clearing of forests for human settlements continued till the beginning of this century after which the pace slowed down considerably. However even in recent times forests have been cleared for human settlements and industrial complexes without the provision for compensatory afforestation.

4. Roads and rail lines

Roads and rail lines are usually laid after clearing forests. This has been a standard practice since earliest times and even today forest land is used for the construction of roads and rail lines. In the hilly areas a fairly large forest area has to be diverted for roads as the forest area is relatively more and besides the actual area for the road a much larger area is destroyed as hills roads involve cutting of the slopes. Moreover the debris of road construction is thrown in forests lying downhill of the construction site.

5. Electric lines

High powered electric transmission lines are taken over forest areas as a result of which all vegetation has to be cleared beneath them. This is another cause of deforestation particularly in the hills.

6. Other developmental works

Forest area is cleared for other developmental works such as-

- canals and irrigation channels
- fruit belts in the hills
- schools and colleges
- tanks and small reservoirs

Factors favouring diversion of forest land

A number of factors favour the diversion of forest land for non-forestry purposes. These are:

(a) **Easy availability** : Forest land is easily and readily available particularly in the period before the enactment of the Forest Conservation Act of 1980. In cases where non-forest land is selected for developmental works its acquisition and payment of compensation is a lengthy process. Considerable litigation in courts may be involved and this takes quite some time.

On the other hand forest land belongs to the state which is initiating the developmental project and it is easy to get this land. Use of forest land also keeps down the cost and time required for completion of the project. The procedure involved in use of forest land is less cumbersome even if exemption has to be taken under the Forest Conservation Act.

(b) **Lack of awareness** : There is a general lack of awareness amongst planners and the general public about -

- the importance of forests
- the role played by them in our economy
- the need to conserve forests
- the protective influence of forests
- the complexity of the forest ecosystem, the destruction of which will cause an irreversible loss
- the role of forests in the everyday lives of the tribals and people living in the rural areas of India.

It is this lack of awareness and perception that results in forests becoming the easiest land for any purpose be it a river valley project , road or any other developmental scheme.

(c) **Low productivity** : Forests have low productivity in commercial terms. As a matter of fact, for long forests were termed as unproductive jungles. The protective functions of forests were realised by planners only a few decades back.

(d) **Lack of economic appreciation** : For a long time only the direct economic benefits of forests were taken into account with no emphasis being laid on the indirect economic benefits such as meeting the fuel and fodder needs of the teeming millions and also benefits such as carbon sequestering.

Preventive and Remedial measures

The following preventive and remedial measures may be adopted for tackling the problem of deforestation.

(1) Proper implementation of the provisions of the National Forest Policy of 1988

(2) The Forest Conservation Act of 1980 is an effective tool against the diversion of forest land for non-forestry purposes. The strictness with which this law is being implemented at present needs to be continued to save our forests from further deforestation. In fact the rate of deforestation has reduced considerably after the enactment of this legislation.

The backlog of area to be planted up under compensatory afforestation should be cleared by taking up a major afforestation drive.

(3) Creation of more reserved forests in the mountainous areas for conserving and protecting our forests.

(4) Transferring the vacant land on both sides of rail lines for afforestation purposes

(5) As far as possible the local community may be involved in afforestation programmes.

CHAPTER 6

FOREST RIGHTS AND CONCESSIONS

In the case of forests, rights are enjoyed both by the owner which in most cases in India is the state and by the people living in the vicinity of the forest. These are permanent rights vested in the forest department by virtue of the state being the owner of the property and by the people who have been using the forest resources for their benefit and daily requirements for the past several centuries. Concessions on the other hand are granted to the people living in the nearby areas for meeting their needs of fuel, fodder and other requirements wherever there exist no rights for these.

The history of origin of rights in India is interesting. In most parts of the country the people who settled in a particular area had been using the nearby forests for the benefit since ages. They functioned as the defacto owners of the forests. At a later stage when small kingdoms came into being the rulers took over ownership of these forest areas while acknowledging the right of the local population to continue to use them in a manner they had been doing for generations. This continued during the British era also and these rights exist even today, irrespective of the fact that the forest area has gone down drastically and the population has increased manifold. In other areas where no rights were recognised by the rulers the people were given concessions or grants for meeting their requirements. These people may have been later settlers in the region.

TYPES OF RIGHTS

Forest rights may be of different types. The various terms used to explain different types of rights have been described below:

1. **Negative rights**: This term describes the right when the forest owner or state is obliged not to do something such as not to stop the flow of water through a forest area or not to bar the right of way of persons using a forest path.

2. **Positive rights**: These are rights of the local people to graze their cattle in a forest or to collect fallen wood for fuel.

3. **Continuous rights**: These rights are continually in operation.

4. **Discontinues rights**: These rights are of intermittent nature and may be available to the holder after gaps of time e.g. trees for repair of houses may be made available once in every 5 to 10 years.

5. **Prescriptive rights**: These are undefined or indefinite rights which are left as such in the terms of the grant. For example the number of cattle that can be grazed by the right holder at a given time in a forest may not be defined.

CATEGORIES OF FOREST RIGHTS IN INDIA

Many different categories of forest rights and concessions are available to the local people living in and around forest areas in various parts of the country. The grant of these rights and concessions may vary from area to area. These have been listed in the following text:

1. **Wood rights :**

This includes rights and concessions with regards to timber and other forms of wood-

(a) Timber for construction of houses

(b) Wood for agricultural implements

(c) Firewood or fuelwood

(d) Dead or fallen wood

(e) Lops and tops

(f) Stumps and roots

(g) Windfall and broken trees

(h) Dead standing trees

2. **Non-wood rights :**

This includes rights and concessions for non-wood forest products-

(a) Bark

(b) Resin and gums

(c) Leaf fodder

(d) Grass, both cutting and gathering

(e) Pasture or grazing of cattle

(f) Collecting seeds and fruits of various species

(g) Collecting litter and leaves/needles from the forest floor

(h) Quarrying or digging pits for sand, gravel etc.

(i) Collecting mushrooms

(j) Hunting and fishing

GENERAL PRINCIPLES REGARDING FOREST RIGHTS

The following general principles may be applied for protecting forests against misuse of rights and concessions:

(1) There is no right to destroy the forest property or to create wanton mischief such as burn a fire.

(2) The rights enjoyed by the local people in no way make them the part owners of the forest property.

(3) Rights can be exercised only till they do not cause any permanent and irreparable damage to the forest ecosystem.

(4) When a right is undefined in character it is deemed to be limited to the actual needs of a person.

(5) A right can neither be sold or bartered.

(6) Rights must be exercised in a way that they cause least interference with regular forest management.

(7) On the other hand the owner of the forest(state in this case) cannot alter the general character of the forest so as to affect rights and concessions of the local people.

ADVERSE EFFECTS OF RIGHTS

Misuse or faulty use of rights and concessions may cause adverse effects on the forest ecosystem.

(1) The forest products obtained by the people for their own use may be sold in the market thus creating a black market and leading to illicit felling and depletion of the forest cover.

(2) Forest products may be extracted in quantities much more than what is required.

(3) Entry into a forest for exercise of rights and concessions may be misused for setting fires in order to settle scores with officials of the forest department.

(4) Felling of green trees or branches though rights may allow for only dry and dead matter.

(5) Encroaching forest areas in the guise of camping in the forest for grazing cattle.

(6) Breach of lopping and grazing rules.

PROTECTIVE MEASURES

The following protective measures may be adopted to minimise the adverse effects of misuse of rights and concessions.

(a) There must be clear demarcation of those parts of the forest in which rights and concessions have been granted. Those free from them or closed against them should have distinct boundaries. The paths along which right of way is recognised both for human beings and domestic animals must be clear.

(b) All working plans must include details of rights and concessions in various forest areas. This must show-

- title deed or other origin of the right
- exact details of the holders and also the provision for successional transfer of rights.
- extent of the right, kind, number, quantity, quality and season of exercise if any.

- mode and conditions of exercise, in some cases the right holders may be bound to help the forest department in detection of forest offences and also in the event of forest fires.

- any payments or charges to be levied on the forest produce extracted or animals grazed.

(c) The exercise of rights and concessions by the local people must be carefully monitored in order to prevent misuse and subsequent damage to the forest.

(d) Some grazier communities enjoy the right to camp in specific parts of a forest. This should be specified and their movement carefully monitored.

Suspension and termination of rights:

Rights may be suspended for a specific period or terminated under the following conditions:

(1) Right of grass cutting, grazing and fuelwood collection in a plantation and regeneration area may be suspended for a period of 10 to 15 years so as to help the regeneration to establish itself.

(2) Right holders are duty bound to render assistance to the forest department in the event of forest fires. In case they fail to do so the forest department may suspend or terminate specific rights.

(3) Rights may be kept in abeyance if the forest is unable to meet the requirements of the right holders.

(4) The forest department may transfer the rights of holders to another area or pay compensation for termination of rights while constituting national parks.

39-78

CHAPTER 7

FOREST FIRES

Intro

Fire, particularly that from wood has been intimately associated with the human race since pre-historic times. It was the discovery of fire and the ability to use it for his benefit that enabled man to develop human civilisation as we know it today.

Fire as a natural and man-made phenomenon has a basic relationship with forestry and it is of vital concern to the forester. Fires are both harmful and beneficial to forests. While they may destroy timber worth crores of rupees, fires may be used as a management tool.

TYPES OF FOREST FIRES

Different definitions have been given to forest fires. These include-

i. From the point of view of the land manager, a forest fire is a wildland fire that is not prescribed for the area as an authorised management tool.

ii. A more descriptive definition explains forest fires as uncontained and freely spreading combustion which consumes the natural fuels of a forest

iii. A generalised description could be, any wild land fire burning with natural fuels.

Forest fires are of different types. The most widely used classification is given below:

1. Underground fire

This is a low intensity fire that consumes the organic matter beneath the surface litter of the forest floor. In many dense forests, particularly those occurring in the wetter parts of

the Himalaya, a thick mantle of organic matter is found on top of the mineral soil. Underground fires spread in and consume such material. They may burn for some meters below the surface and spread entirely underground.

Such fires are difficult to detect and control. They may continue to burn for long periods. These fires have also been termed as peat or muck fires. In some countries, these have been referred to as ground fires.

2. Ground fire

This fire burns the herbaceous growth on the forest floor together with the layer of organic matter in various stages of decay. Forests in which slash from felling remains to be suitably disposed are prone to this type of fire.

The distinction between underground and ground fires is not very clear and often the former type of fires turn into ground fires after smouldering for some time.

3. Creeping fire

This fire usually occurs in forests devoid of a significant ground flora. The flames are low and they spread along the forest floor burning the lower storey only. This fire does not burn underground unlike the case of ground fires.

Creeping fires advance slowly in the absence of a strong wind. It may flare up if the wind picks up and turn into a strong breeze.

4. Surface fire

This type of fire burns not only the ground flora but also engulfs the undergrowth and middle storey of the forest. Even the low trees and poles of the larger species are engulfed by surface fires. It causes considerable damage to the forest by destroying the young regeneration and even the pole crop of the favoured species.

5. Crown fire

This is the most devastating type of fire which burns even the crowns of the tall trees. They may occur in coniferous forests during strong winds. This is the most devastating type of forest fire and may cause immense loss of life and property.

Crown fire is the most difficult to control as it moves over the heads of the fire fighters on the ground. As it is fast moving it poses a grave danger to them. It remains almost uncontrolable till it drops down to the ground.

The above types of fires are not independent of each other and one type of fire may lead to the other. For example an underground fire may slowly develop into a ground, creeping, surface and finally into a crown fire if efforts are not made to check and control them effectively.

Another classification of forest fires into different types could be no the basis of causative factors such as,

(a) Natural fires-those which originate due to natural causes such as lightning, rolling stones and rubbing together of dry bamboos.

(b) Accidental or unintentional fires-these are accidental fires set off by the action of human beings e.g. throwing of unextinguished matches in the forest or accidental spreading of fire set to agricultural fields.

(c) Intentional fires-in some cases the forest is deliberately set on fire by human beings mainly as a management tool e.g. control burning during the spring season.

CAUSES OF FOREST FIRES

In India forest fires may be caused in many different ways-

1. **Natural causes** :

Forest fires originate due to natural causes such as-

- lightning may lead to the occurrence of forest fires.

- the friction generated by rolling stones in mountainous areas may lead to forest fires particularly in the dry season when there is considerable combustible material present on the forest floor. Even a small spark is enough to generate a fire which may be fanned by winds.

- in bamboo areas, even the rubbing together of culms of dry bamboos which grow close together may cause the occurrence of forest fires.

- volcanic eruptions too lead to forest fires though not in India.

2. **Accidental causes**:

These causes include the accidental or unintentional reasons for the origin of forest fires. Many forest fires in India may originate due to accidental or unintentional causes such as those listed below-

- unextinguished camp fires of trekkers, labour camps, nomads moving through the forest with their animals or the fires of road side charcoal panniers when not put out properly may lead to devastating forest fires.

- sparks from railway engines (mainly steam locomotives) are also the cause of forest fires. However with the discontinuation of steam locomotives, fires originating due to this cause have become very rare as diesel and electric

locomotives do not produce sparks capable of starting forest fires.

- travellers, picnickers, nomadic graziers, villagers or even forest labourers may carelessly throw unextinguished cigarettes, bidis or match sticks in forest areas. When the wind picks up these small sparks build into forest fires capable of destroying valuable timber worth crores of rupees.

- in many parts of India, travellers and the local people carry torches of wood while passing through forest areas at night. When thrown aside carelessly these become the source of forest fires.

- the villagers set fire to their agricultural fields after a harvest. When these are not put out completely they may spread to the adjoining forest areas.

- during controlled burning operations carried out by the forest department negligence on part of the staff may lead to uncontrolled forest fires.

- careless handling of resin during resin tapping in the summer season may generate heat enough to start a fire if the wind begins to blow at high speeds.

3. **Intentional causes**:

This includes causes where the intention is clearly to set fire to the forest both as a management tool and for other purposes. This includes-

- controlled burning of forest areas is done by the forest staff just before the onset of the fire prone season. The aim is to burn all the combustible

material in the forest before the dry season which is when fires are the most frequent.

- the local people often set fire to the forest before the rainy season in order to get a good growth of grass for their cattle in the monsoons. Though this activity is illegal they manage to start forest fires which develop into devastating infernos.

- wild grass is often set on fire by tribals to search for wild animals and their nests/homes.

- in some cases miscreants may set the forest on fire in order to settle scores with the forest department or its staff.

- forest fires may be started in order to hide the stumps of illicit fellings carried out by anti-social elements.

FUELS

Fuels for forest fires vary widely in their distribution, physical characters and their impact on the behaviour of the forest fire.

Types of fuels:

The main types of fuels for forest fires are :

1. **Ground fuels** : This includes all combustible material below the loose litter of the surface. The following materials constitute ground fuels-

   - humus in various stages of decay
   - roots of trees and shrubs.
   - peat and muck.

Ground fuels support glowing combustion rather than a flame. They tend to reaction their higher moisture contents and will not ignite till the moisture content drops down to below 20%. However combustion is very persistent once ground fuels have ignited.

2. **Surface fuels** : This includes all the combustible material on the forest floor. The following constitute surface fuels-

   - tree leaves and fine litter
   - grasses, weeds, ferns and other herbaceous plants
   - low brush, seedlings and saplings of trees.
   - fine deadwood on the forest floor
   - large logs and stumps
   - roots of trees

Surface fuels ignite very readily and provide the basic combustible material for forest fires.

3. **Aerial fuels** : This includes all combustible material live or dead located in the understorey and the upper forest canopy and separated from the ground by more than a meter. The main aerial fuels are-

   - branches and foliage of trees
   - trees and shrubs of the understorey
   - standing dead trees
   - mosses, lichens and epiphytic plants on trees

As the forest fire spreads the aerial fuels provide much needed combustible material to it. In the case of crown fires the inferno spreads by consuming aerial fuels.

FUEL CONTINUITY

The continuity of fuels is the primary factor that helps in spreading of forest fires and proves to be crucial in controlling them. This is due to the fact that they transfer heat by radiation, conduction and convection. Continuity is a relative term denoting both forms of continuity viz, vertical and horizontal. These are essential for the spread of the fire and must be taken into account while planning forest fire control.

COMBUSTION

The combustion process of fuels is also important in understanding the behaviour of forest fires. Combustion is one of the many types of oxidation processes. It is a chain reaction which takes place rapidly at high temperatures. There are three phases of combustion of forest fuels-

(a) **Preheating phase** - In this phase the fuel is brought to its kindling or ignition point ahead of the flames. This drives off moisture and starts the generation of flammable hydrocarbon gases.

(b) **Second phase** - Ignition of the gases starts the second phase and supplies more heat to quickly complete the distillation process and the resultant flaming combustion.

(c) **Third phase** - In this phase the residual charcoal is burnt. A certain quantity of carbon monoxide is formed as an intermediate product which burns with a low blue flame to produce carbon dioxide. However most of the time carbon burns as a solid.

The quantum of heat released varies from fuel to fuel and also differs in the various stages of combustion. In case the process of combustion is not complete, some of the distilled hydrocarbons will remain suspended as very small droplets of liquid. These will float in the air alongwith the residual carbonised particles.

Factors affecting rate of energy release:

The following factors affect the rate of energy release in forest fuels-

- quantity of moisture in the fuel
- wind movement, its direction and speed
- modes of heat transfer
- fuel size and arrangement

FIRE BEHAVIOUR

This is a general descriptive term used for describing what a fire does. A complex chain reaction process is formed by the ignition, buildup, propagation and decline of any large forest fire. However the behaviour of no two fires is alike. There are a number of parameters that have a bearing on the behaviour of fires. These include the nature and type of fuels, winds, prevailing temperatures etc. Typically, one part of a fire spreads more rapidly than the others. This is due to the effect of wind and terrain or a combination of both. Thus a fanlike pattern is created with the fastest spreading portion at the apex or farthest from the point of origin.

The following parts may be distinguished in the perimeter of a forest fire:

(a) Head or head fire is that part of the perimeter which enlarges itself very rapidly.

(b) Flanks or side fire is that part of the perimeter which moves at right angles to the direction taken by the head fire.

(c) Rear or base or tail of the perimeter is that part of the fire which spreads in a direction opposite to the direction of the head fire.

The salient features of forest fire behaviour are discussed below:

1. The rate of spread of a fire decreases from the head to flank and rear depending on-

   - nature and direction of wind
   - slope conditions
   - nature and availability of fuels.

2. Usually the period of maximum heat output of the flaming fuels at any one spot is sustained only for a few minutes. As a result the number of small fires burning together build up a much higher level of heat energy than will develop from a single fire front moving through the same area.

3. Variations in burn pattern are influenced by -

   - speed and direction of the surface winds
   - conditions of topography
   - local variations in fuel
   - nature of vegetation

   There is a marked influence of both wind and topography on the transfer of heat by radiation

and convection. If there is no wind and the topography is flat it is expected that the fire will spread at more or less the same rate in all directions so that the initial pattern of spread is circular. This then tends to change with wind and slope.

4. A smoke plume is produced in the case of a low energy fire or one that is smouldering or in the process of dying out rather than in an active convection column. The main features of a smoke plume in forest fires are-

   - lack of pronounced vertical motion
   - relatively light colour
   - relatively high degree of transparency

5. An active convection column is produced in a high energy fire with a strong vertical component and a typical inside-out rolling motion. If there are very strong winds, the convection column is tilted or displaced often retaining its identity with the convection column almost horizontal downwind.

ADVERSE EFFECTS OF FOREST FIRES

Fires have many different effects on the forest ecosystem. These are both beneficial and adverse the latter being more pronounced than the former. The adverse effects of forest fires have been discussed in the following text:

1. **Damage to trees**:

Any tree is liable to be killed by fires of sufficient duration and intensity. As a matter of fact resistance of trees to fires becomes immaterial in case of fires of very high intensity and long duration as all species and trees of all sizes are liable to be killed

in extreme cases. However if the fire is of low intensity and relatively short duration only a part of the forest stand is killed and the relative difference between trees having resistance to heat and those prone to injury become important. Fires causing only partial kill are much more common.

The damage caused to a forest varies with the following-

- species
- intensity and duration of the fire
- age of the trees
- season in which the fire has occurred.

In general broadleaved trees are more affected than conifers. Deodar, fir and spruce are more prone to injury by fire while chir pine due to its corky bark is partly resistant. However trees that are being tapped for resin may be damaged more as fire tends to burn in the dry resin channels for a relatively longer duration of time.

Crops of younger age are more susceptible to fire. With age the bark thickens and this provides protection against fire damage. Green trees are less damaged than drier ones.

The following factors have a bearing on the susceptibility of trees to damage by fires-

(a) Initial temperature of the vegetation

(b) The size of the critical tree portion affected by the fire and its morphology.

(c) The thickness and character of the bark

(d) Branching and growth habit

(e) Rooting habit of the tree

(f) Organic material covering the mineral soil

(g) The flammability of the foliage

(h) Habit and character of the stand

(i) Season and growth cycle

On the basis of their resistance to damage by fire, trees may be classed as fire resistant and fire sensitive. Thus while chir pine is a fire resistant or fire hardy species, spruce and fir are extremely prone to injury by fires.

The following broad forms of injury may occur to trees from forest fires:

(i) physical damage to the tree which includes wounding of the bole, mainly near the base, root injury, defoliation, damage to the branches and other injuries resulting directly from the fire.

(ii) adverse effects caused by diseases and insects induced by fire injury or damage.

2. **Damage to regeneration** :

Fires cause immense damage to the regeneration or young crop as even a low intensity fire is enough to have adverse effects on the vegetation at the ground level which includes the new recruits , seedlings and saplings. Ground , surface and creeping fires immediately cause harm to the regeneration.

(a) **Artificial regeneration** : Forest fires cause immense damage to plantations and areas regenerated by sowings. Substantial amounts are usually spent on regenerating areas by artificial means and this goes waste due to the effects of a fire. Moreover extra effort has to be put in to rehabilitate a fire burnt area before it can

be adequately regenerated again by artificial means. These areas have to be kept closed for grazing for longer periods and the success achieved is usually less in the case of an area unaffected by fires.

(b) **Natural regeneration** : Seedlings are burnt and killed by forest fires even of a moderate intensity. When the fire is not so fierce it kills the roots of the seedlings as a result of which regeneration appears in the form of coppice seedlings but in this case too there is loss of growth. These coppice seedlings too may be repeatedly burnt thereby creating serious management problems.

3. **Loss of productivity :**

Forest fires cause a serious loss of forest productivity. All forests no matter what their productivity is tend to loose their productive power due to forest fires particularly in the case of repeated burning year after year. The crop density and annual increment are reduced as a result of forest fires.

There is also loss direct and indirect loss of productivity in the following manner-

(i) less grass and leaf fodder production

(ii) less availability of fuelwood and small timber

(iii) loss of production in terms of timber and non-timber forest products

4. **Reduction in protective functions :**

Forests play important protective roles particularly in the mountainous areas. This includes-

- conservation of soil and water
- maintenance of ecological stability
- amelioration of climatic conditions

Forest fires lead to a reduction in the protective functions of forests. There is ecological instability in the entire tract as a result of repeated burning of the forests.

5. **Effect on vegetation :**

Besides adversely affecting trees and the forest, fires also have permanent adverse effects on the vegetation as a whole. There may be partial or complete change of the existing vegetation type caused by retrogressive succession. If fires occur over a longer period of time then a shrubby vegetation may develop.

6. **Effect on microclimate :**

It is a well known fact that the forest cover has a significant effect on the microclimate. There is a strong impact on air temperature. The forest has a capacity to lower the maximum and increase the minimum temperatures within and under the canopy particularly near the ground. The maximums are decreased more than the minimums are increased. Average changes of only a few degrees are important for modification of the microclimate.

There is a strong effect of light, temperature and soil moisture, all of which are closely associated with the vegetative cover on the regeneration of trees and other forms of vegetation. On sites that have been recently burnt by fires, the surface temperatures may reach lethal levels and prevent the establishment of seedlings. Even the growth of established seedlings and saplings is affected by temperature and soil moisture.

Another important microclimatic factor which is adversely affected by forest fires is air movement. Under a fully canopy of a

mature forest, air speeds usually do not exceed 10 km per hour within 1 mt. of the ground irrespective of the wind velocities above and outside the forest. Winds speeds and patterns of air movement in a forest in relation to open conditions increase as a function of height above ground and stand density.

The levels of relative humidity are always higher in a forest than outside and generally speaking the more the dense and complete the forest cover is, the more is the relative humidity. This is a result of the combined effect of lower air temperature, less wind speeds and lower transpiration from the trees. Fuels dry more slowly in a complete canopied forest and thus there is less danger of forest fires.

6. **Effect on soil :**

Forest fires have far reaching effects on the soil. The following four parameters have a bearing on the effect of fires on the soil-

- frequency of the fire
- duration and intensity of heat
- conditions on the forest floor
- general soil characteristics.

(a) **Soil heating** : The surface soil is fairly prone to change due to heating as a result of forest fires. Soil heating affects the following -

- organisms present in the soil
- organic matter content
- colloidal structure of the soil.

Heat from forest fires is transmitted to the soil by convection, radiation and conduction. The temperatures reached depend on the parameters listed below;

(i) Intensity and duration of the fire

(ii) The thermal conductivity of the soil

(iii) The physical and chemical composition of the soil

(iv) Character, amount and behaviour of unincorporated organic matter that may be present overlying the mineral soil.

(b) **Physical effects on soil** : Forest fires cause the following adverse physical effects on the soil-

- There may be severe accelerated erosion and increased surface runoff due to exposure of the surface soil through destruction of the vegetative cover as a result of repeated fires.
- In case of heavier soils there may be compaction of the surface due to repeated fires thereby exposing the mineral soil. Muddy water soon seals the surface layers and lowers infiltration capacity. However sandy soils may remain unaffected by this phenomenon.
- The soil surface may be blackened by the effect of repeated fires thereby creating subsequent problems for regeneration of the soil.
- Forest fires lead to a reduction of soil moisture particularly near the surface.

(c) **Chemical effects on soil** : Forest fires may have the following adverse chemical effects on the soil-

- There is loss of nitrogen in bound form into the air from combustion of organic matter.

- Lowering of soil acidity particularly near the surface.

- Loss of soluble nutrients through leaching.

(d) **Biological effects on soil** : The following biological effects may occur in the soil due to forest fires-

- Reduction in the number of soil organisms near the surface.

- Death of soil bacteria.

7. **Effect on wild animals :**

Forest fires also have a profound impact on wild animals and their habitat. The adverse effects are more. These have been outlined below:

(a) Forest fires may burn the eggs of birds, young ones and even adults of all types of animals.

(b) The habitat , shelter and food of wild animals are destroyed in forest fires. The first casualties include nests of birds which usually occupy branches of trees and shrubs.

(c) Wild animals are forced to migrate away from fire burnt areas.

8. **Effect on aesthetic values :**

Forest fires lower the recreational and aesthetic value of a forest. Fire burnt areas are neither good to , look at nor do they remain a place to visit. The blackened soil, burnt shrubs and grasses and charred stems do not present a pleasant appearance.

PREVENTION

Prevention is very important for protecting forests from fires. There are many measures which can be taken for preventing or minimising the occurrence of forest fires. Preventive measures are both direct and indirect in nature. They have been discussed in the following text.

1. **Fire danger rating**

Fire danger rating pertains to forecasting the likelihood of occurrence of forest fires during a particular period of time, day or week. According to the US Forest Service this is a fire control management system that integrates the effects of selected fire danger factors into one or more qualitative or numerical indices of current protection needs. Though this system has not been adopted on a wide scale in India it is a standard practice to forecast the fire danger rating of most forest areas during the fire season in developed countries.

Five to seven fire danger classes are made and the risk assessed from time to time in the basis of the following parameters :

(i) Barometric pressure

(ii) Wind conditions

(iii) Precipitation, current, seasonal and yearly or cyclic

(iv) Temperature conditions

(v) Relative humidity

(vi) Ground water level

(vii) Condition of the vegetation

(viii) Ignition sources

(ix) Fuel moisture

Presentation : The fire danger rating is presented in the form of classes on a circular board or chart with each class having different colour codes such as green, blue, yellow, orange and red.

Uses : This is an effective measure helping to prevent the occurrence of forest fires and also in taking control measures in case of an outbreak. The main uses and applications of fire danger rating are listed below :

(a) Forecasting the probability of occurrence of forest fires so that the staff can remain in a state or readiness

(b) Informing the public of the fire danger

(c) Cancellation of control burning operations if any are planned during that period

(d) Restricting the movement of people inside the forest

(e) Manning action stations and watch towers

(f) Appraisal of the damage caused by fires

2. **Goodwill of the local population :**

In India human beings particularly those living in and around forest areas are responsible for as much as 90% of forest fires. Hence their goodwill is essential for preventing the occurrence of fires. This is a public oriented measure indirectly responsible for fire prevention.

The goodwill of the local people can be said to be an insurance against forest fires. It helps to prevent forest fires in the following manner -

- the local people will not set fire to the forest for obtaining a good growth of grass following the rains.
- they will avoid throwing away unextinguished matches, bidi butts and torches in the vicinity of forests.
- instances of deliberate setting fire to forests to settle scores with the staff will be reduced.
- they will immediately report the occurrence of a fire to the nearest forest guard hut or range office.

A number of steps help to win the goodwill of the local people as far as the forest department is concerned-

(a) Speedily processing their applications for various purposes that may be pending with the forest department

(b) Avoiding unnecessary delays in allowing them their recognised rights and concessions

(c) Involving the local community leaders in efforts to prevent the occurrence of forest fires.

(d) Avoiding undue harassment of the local people.

3 **Educating the masses :**

Educating the masses is another indirect public oriented fire preventive measure. It is necessary to educate the masses with regard to the following-

- the causes of forest fires
- the damages caused by them, both long term and short term
- the role which the local population can play in preventing forest fires.
- help and assistance that may be rendered by the common people in the event of an outbreak of forest fires.

The target group that must be educated under these programmes are-

(a) School children and college students

(b) Women folk particularly those who go to the forest areas everyday for their needs of fuelwood and fodder.

(c) Community leaders and village elders as they have a considerable influence on local affairs

(d) Farmers who work in the vicinity of forests

(e) Teachers and government servants living and working in and around forest areas

(f) Tribal and nomadic shepherds living in and around forest areas

(g) City folk visiting forests for recreation.

There are a number of ways in which the masses can be educated about various aspects of forest fires. These can be both informal and formal methods listed below:

(i) By using the mass media

(ii) By lectures in schools, villages and fairs

(iii) By talks before village bodies and panchayat meetings

(iv) Through the mass media such as radio and television

(v) Through newspapers and magazines

(vi) Film , video and slide shows

(vii) Taking small groups of people to fire burnt areas so as to show them the actual damage that has been done

(viii) Through posters, pamphlets and leaflets.

The extension and publicity divisions of various state forest departments can be involved in this work with the actual interaction with the masses being done with the help of the local community bodies.

3. Restrictions on certain activities :

The forest department can impose restrictions on certain activities within and around forest areas during the fire season. There are provisions under the Indian Forest Act 1927 and other legislations for this. The restrictions could be-

(a) Collection of non-wood forest produce particularly honey as this involves the production of smoke to drive away the bees.

(b) Collection of fallen horns and bones of dead wild animals as grass is burnt so as to readily sight these items which may be lying hidden in the undergrowth.

(c) No entry in forests for recreation purposes such as camping when there is a high risk of fires

(d) Use of acid by resin tappers during the fire season

(e) Grass cutting on high fires risk days

(f) Felling of trees on high fire risk days

Tribals and other communities living in the forest could be discouraged from kindling fires in areas other than their camps during the fire season. Even the labourers of the forest department and PWD could be asked not to kindle fires for sharpening their hand tools or for preparing tea etc near forests on high risk days. Though in some cases legislative provisions may not be available for enforcing these restrictions, this can be done by persuasion and convincing the people involved for the need to do so.

4. Reward and punishment :

A system of reward and punishment also helps in the prevention of forest fires. This could be used in the following manner on the basis of existing or new legislative measures-

(a) Suitable rewards for people who render assistance during the out break of forest fires. This will serve as an incentive for future occurrences

(b) The local community or panchayat may be given cash incentives for helping the forest department in the case of fires. They can also be provided with additional benefits such as grants for roads, dispensaries and community centres.

(c) The rights of a person or group of persons who do not render assistance in the event of forest fires may be suspended for a specific period of time under the provisions of the Indian Forest Act. This will prove as a deterrent for future as in

most cases the holders of rights and concessions in a forest are bound to come to the aid of the forest department in the event of a forest fire. A procedure has been prescribed for this which must be followed for the temporary suspension of these rights and concessions.

5. Legislative measures :

The existing provisions of the Indian Forest Act can be used for prosecuting persons guilty of starting forest fires. All cases of forest fires may be investigated either by the forest department or through the local police for possible involvement of miscreants in starting the fire. In case an involvement is found the guilty persons must be proceeded against in the court of law so that others may be deterred from commiting such offences.

Cases where the forest staff is guilty of dereliction of duty must be taken up for immediate departmental proceedings.

6. Signs and posters :

Putting up signs, posters and notices about the dangers of forest fires in and around fire prone areas is another indirect prevention measure intended for public awareness. These could be in the form of notices, signboards, posters and pamphlets. The messages to be displayed in these include-

- dangers of forest fires
- risk of fire in that particular locality or area
- what the public should do in the event of a fire
- why forests need to be protected against fires

These could also be put up on roads running through forests, prominent places in the towns and villages near forest areas and also in schools and community centres.

7. Hazard reduction:

This is an important direct fire prevention measure that primarily pertains to the removal of fuels exposed to sources of high risk so that fires do not occur or atleast their occurrence is minimized. Hazard reduction involves the following broad principles(after Brown and Davis 1959):

(a) Removal of all ignitable fuel in limited areas of special risk. This may involve the burning of grasses and shrubs in order to prevent occurrences of forest fires during the dry season. The main aim is the automatic prevention of ignitions by removal of fuels.

(b) Removal of all fuel in a strip close to or around the source of risk so as to confine any fire that may occur to a limited area of isolated extent.

(c) Removal of fuel in a strip in order to exclude the fire from a high value or high hazard area. This includes the creation of fire breaks around a forest plantation.

(d) Removal of fuels to reinforce natural fire breaks and also for creating new ones with the help of which an area can be broken up into blocks for helping to control forest fires. Access roads and firebreaks can be suitably combined for this purpose.

(e) Use of prescribed burning when coarse and intermediate fuels are moist to safely remove flash fuels from considerable areas. This may also be adopted in the case of smaller areas to strongly reduce fuel hazards.

(f) Using cultural means such as pruning, thinning and removal of undergrowth for breaking the

vertical continuity of fuels and the horizontal continuity of tree crowns in coniferous forests.

(g) Removal of dead snags or trees that would help spot fires if ignited.

Careful planning and implementation are needed for the application of these hazard reduction measures. Of the above, firebreaks and control burning are the most commonly adopted hazard reduction measures adopted in India. These have been under separate headings in the following text.

8. Firebreaks and Firelines :

A firebreak is a natural or constructed barrier that is used for controlling or checking fires that may break out or to serve as a control line from which various fire fighting operations may be carried out. Firelines are a type of fire breaks that are formed around or within a forest so as to break the path or progress of a fire.

Firebreaks may be formed by the following -

- a lane or strip from which vegetation has been cleared.
- a road or inspection path
- a river, stream , lake or any other waterbody of reasonable dimensions
- a ridge top partially cleared of inflammable material

Formation and maintenance of firebreaks:

Firebreaks may be constructed or formed in the following manner :

(a) **Mechanical** : Most firebreaks are constructed by mechanical means with the help of common land clearing equipment such as buldozers, ploughs and usual hand tools e.g. shovels and spades. Where the forest cover is not fully removed with larger trees being retained as shaded firebreaks, some clearing and burning by hand is required. These have to be maintained by mechanical means usually on an annual basis. These operations are prescribed in many working plans of India.

(b) **Chemical** : Herbicides may be used for clearing and maintaining firebreaks. These may be of two general types:

- inorganic poisons which kill all vegetation and sterilize the soil for sometime.
- toxic organic compounds of harmone derivative which are relatively more selective in their lethal effects usually do not leave any poisonous effects on the soil.

In developed countries, fire retardant chemicals are also used in firebreaks. These remain effective even when dry and are useful in creating temporary firebreaks.

(c) **Vegetation** : Lush green vegetation is also a good firebreak so long as it remains in a green condition. This could be in the form of pastures. However it is difficult to maintain such vegetative firebreaks in a green condition during the dry season which is the fire prone season in India.

(d) **Burning** : Burning for clearing firebreaks is also adopted so as to burn the inflammable material that may be lying in the forest and also to encourage the growth of green grass in the firebreak.

Firelines:

Firelines are firebreaks consisting of cleared strip both inside or along the periphery of forest areas which the following purposes-

- to prevent the fire from crossing over from one part of the forest to another or (in the case of external firelines) to stop the fire from affecting a particular forest.
- to serve as a fire free strip on which the fire fighters can be deployed for fire control operations
- in the event of an outbreak of fire these lines help to ensure the movement of men and equipment from one part of the forest to another without any danger from the fire.
- they help to limit the damage caused by a fire
- counter firing, a tool against fierce fires can be done from firelines which serve as base.

Firelines have a width of about 10 mts or more depending on the terrain and the chances of occurrence of forest fires. They are cleared of all vegetation. The firelines have to be maintained every year or else they may be soon covered with vegetation which adds to the fire hazard. Adequate provisions are made in the working plans for the construction and maintenance of fire lines.

In forests where there are no fire lines a phased plan is usually prescribed so that all forests have firelines after the said period of time. In the same way there is a regular programme for maintenance of the lines. It is the responsibility of the forest range officer for constructing and maintaining the fire lines.

Fire lines are of permanent nature and may be of two types :

(a) **Internal fire lines** : These firelines are located within or inside a forest. They serve to prevent the spread of the fire from one part of the forest to the other, thereby restricting the

damage. At times rivers, streams, inspection paths, compartment boundaries or motor roads may also serve as firelines. In the absence of these, internal fireline of width more than 10 mts have to be constructed and maintained. In many forest areas, firelines run for many kilometers.

(b) **External firelines** : These are maintained along the boundary or periphery of a forest in order to prevent a fire from entering the forest.

Even though theoretically firelines must be cleared of all vegetation this may not always be possible due to the high cost involved. In these cases a 1.5 to 2 mts wide strip on the two outer edges of the fireline are cleared of all vegetation. This is the grass free strip and the grass that has been cut from here is piled on the inner part of the fireline and set on fire so that the inflammable material that is present is also burnt. After firing in this way the inner part of the fireline other than the grass free zone is also partially cleared.

9. **Control or Early burning :**

This involves the burning of all the inflammable material in a forest before the onset of the dry season which is also the fire season. The object is to reduce the fire hazard so that the chances of an outbreak of fire are minimized.

In India controlled or early burning is usually done in late February or early March during the period that marks the transition between winter and summer. It may be delayed for a couple of weeks in the hills where winter continues till late March. Two burnings may be done if possible. The first firing destroys all the shrub growth whereas the second one consumes the fallen twigs, branches and other inflammable material.

The following operations are involved in this:

(a) The forest area to be control burnt is visited by the range officer well in advance and the operation planned out in detail particularly with

respect to the requirements of manpower and other logistical support.

(b) The firing party moves to the forest a day or two in advance of the actual day of burning so as to familiarise themselves with the terrain and requirements of the task at hand.

(c) The actual timing of the operation depends on the weather conditions particularly wind. It is advisable to carry out the burning in the evening after dark so that the progress of the fire can be easily monitored and corrective measures taken in case it begins to get out of hand.

(d) The manpower engaged for this purpose should be from the local area as they are familiar with the terrain. They are formed into two groups each being further sub-divided into a number of teams depending on the local conditions. They are closely supervised by the forest staff mainly the beat guard concerned, guards from adjoining beats, foresters while the range officer mans the control station set up for this purpose.

While one group carries out the firing with the help of torch wood, the other stands by with green bushes and wet gunny bags to beat out the fire in case it tends to become out of control. The firing is done in only one direction with a fireline or road as the baseline.

(e) The control burning continues without a break till the area to be so treated is free of inflammable material.

(f) Thereafer the firing stops and the second group moves into the forest to put out the smouldering shrubs, grasses and twigs.

(g) The range officer inspects the area and makes sure that the fire has been put out before the controlled burning party pulls out from the forest. This has to be ensured, lest the fire picks up with the wind and turns into an uncontrollable inferno. Extra precaution has to be taken while control burning forest areas near human habitation, roads, rail lines and other important features.

Constraints:

There are a number of constraints in successfully carrying out control burning operations-

(i) Uncertain weather conditions make exact planning difficult. At times the manpower meant for carrying out control burning may have to wait for some days for the right weather conditions.

(ii) Some forest types are not suited for control burning

(iii) Negligence on the part of the staff may lead to uncontrolled fires that may destroy vast areas.

Triennial control burning programme:

The frequency in which a forest has to be controlled burnt varies from species to species, locality conditions and the availability of funds. To maintain uniformity in most forest divisions of India a triennial control burning programme is prescribed in the working plans. According to this every forest has to be control burnt once in three years. Thus the number of forests prescribed for control burning each year is known well in advance so that the operations can be planned accordingly by the range or divisional level staff.

FOREST FIRE CONTROL AND EXTINGUISHING

Forest fire control and extinguishing is a specialised job in which the staff has to be adequately trained. The following

methods are adopted for the detection, control and extinguishing of forest fires that may break out inspite of the preventive measures that may have been taken by the forest department.

1. Detection:

Detection of forest fires is important for early control. Very often due to the remoteness of the tract, forest fires may remain undetected for a day or two during which time they cause loss of life and property. Thus adequate measures have to be taken for the early detection of outbreaks of forest fires. These involve the following:

(a) **Fire watchers** : In India fire watchers are usually kept on daily wage basis during the fire season by the forest department from amongst the local population.

(b) **Watch towers** : These are permanent structures made from wood or iron having a height of more than 30 mts with a small space at the top for two or three persons. The watch towers are usually constructed in the plains at locations providing them with a good view of the surrounding forests.

(c) **Look out points** : In the hills high mountain tops with a commanding view of the surrounding country side are selected as lookout points. A small wooden or tin structure may be constructed there for providing shelter to two or three persons.

(d) **Detection and communication** : The watch towers and lookout points are manned all 24-hours during the fire season by fire watchers. They are provided with a compass, map of the surrounding area and telephone link with the range office. As soon as they detect a fire, its

location is plotted on the map with the help of the compass and the exact bearings communicated to the range office immediately.

With the help of bearings from two different watch towers or lookout points the fire fighting party located at the range office can pin point the exact location of the fire. The fire watchers continue to monitor the path of the fire and report back the details to the range officer.

(e) **Aerial patrols** : In developed countries, aerial patrols by small aeroplanes and even helicopters are made for detecting the occurrence of fires in otherwise remote and less accessible forest areas. As soon as a fire is spotted its location is reported back to base by the pilot over the wireless.

Nowadays electronic devise such as infra-red aerial scanners and automatic electro-fire detectors are also used for the detection of fires. These devices are carried abroad patrolling aircraft and any incipient fires are reported back to base immediately.

(f) **Local people** : The local population too helps in the early detection of forest fires, particularly in remote areas. They usually tend to inform the nearest forest office in such cases. The cooperation of the local population may be enhanced by offering cash incentives for early reporting of forest fires.

2. Communication:

Communication about the outbreak and progress of a forest fire is essential for combating it effectively. In India several means are used for such communications-

- through special runners, messengers moving on foot, horseback or on a vehicle.
- departmental telephones
- wireless links

A base station is maintained for these communications so that adequate action can be taken. This may be the range office , block headquarters or guard hut. Quick communications are very essential in fire control operations.

3. Quick action :

Quick or early action is required for effectively controlling forest fires. This can be done in the following manner

(i) Locating adequate fire fighting personnel(or squads) at pre-selected points so that they may reach the forest on fire as early as possible.

(ii) These squads maintain regular communications with the range office and watch towers-look out points.

(iii) They are provided with transport, tool and other fire fighting equipment for a quick response.

4. Personnel/Labour :

The fire fighting personnel /labour consists of the following -

- staff of the forest department who play a supervisory role in fire fighting squads.
- local labour engaged for this purpose
- villages who may volunteer to assist in fire fighting operations at the outbreak of a fire

particularly when the fire is threatening their fields or villages.

The fire fighting squads have to be on the alert all the time. They are based at a central location which may or may not be the range headquarters.

5. **Water :**

Water is essential for fire fighting both for putting out the fire where sufficient quantities are readily available and also for the fire fighters. Arrangements must be made for water at the base and also for the fire fighting squad. Small tankers full with water may be parked at the base. These can move with the fire fighting party. All sources of water such as rivers, lakes, ponds and springs must be known to the personnel so that water can be arranged at the location of the fire if possible.

6. **Tools and other requirements :**

In many cases it is not possible to put out the fire with water. Other methods have to be adopted. For these a number of hand tools are needed. These include spades, pick-axes, rakes and axes. These tools are required for the following purposes-

- for cuttings shrubs and grasses to beat out the fire
- for digging earth
- for pushing away burning wood and branches and raking the forest floor
- for digging small ditches

These tools must have wooden handles as metal handles tend to get over heated during fire fighting operations.

Food is another important requirement at the site of the fire as most fire fighting operations continue non-stop for more than 15 to 16 hours during which period the fire fighters need nourishment. The food should be such that it provides quick nourishment and is able to readily replenish the sapped energy of the persons engaged in combating the fire.

7. **Transport :**

Transport is required both for men and material for effective fire control. The main requirements for adequate transport facilities are-

- a good network of jeepable roads, mule tracks and footpaths.
- deployment of enough jeeps and pack animals at the base camps of different fire fighting parties.
- the main facilities for transport consist of jeeps or small trucks for ferrying men, tractors with tankers for water and tools. Mules may be used in the mountains where there are few roads. In case vehicles/mules are not available in the required numbers with the forest department they may be hired for the duration of the fire season.

FIRE EXTINGUISHING

Fire extinguishing pertains to the actual control or putting out the fire. A number of methods are used for extinguishing forest fires in India depending upon variables such as-

- duration and intensity of the fire
- availability of water, earth etc with which the fire may be put out.
- availability of manpower.

(a) **Extinguishing with water:**

Water is suitable for putting out small forest fires or those which have just started. It is thrown on the flames so that the fire is put out. However large fires cannot be extinguished by water unless it is available in sufficient quantities near the location of the fire.

Even if water is available in large quantities nearby, it is difficult to bring it to the flames and many buckets or long pipes may be needed. Nevertheless even if the fire it put out by other means, water is required for extinguishing smouldering stumps, twigs etc and also to quench the thirst of the fire fighters who may be on the job for several hours at a stretch.

(b) **Extinguishing with earth:**

Earth or mud is a good fire extinguisher as it cuts off the oxygen supply to the latter. It is also available locally and can be readily dug up at site of the occurrence of the fire. It is dug up and thrown on the fire in large quantities thereby putting out the flames. Earth is also used for putting out smouldering stumps and twigs.

For this purpose the fire fighting party carries hand tools for digging earth such as shovels and rakes. However use of earth for fire extinguishing has the following disadvantages:

- considerable quantities are needed for putting out big fires
- digging up large quantities of earth takes considerable time and by then the fire may have spread to other areas.

(c) **Extinguishing by beating:**

Another important method of controlling fires is to beat them out with green bushes or wet gunny bags. The fire fighting

squad stands in a line and the fire is beaten out. This is the best way of controlling surface fires.

The flames are struck diagonally as if the angle of strike is vertical the sparks may spread the fire to unburnt areas. A number of persons stand in reserve to control the flames which may have escaped being beaten out by the main squad.

(d) **Extinguishing by counterfiring:**

This is the only method of controlling fierce crown fires. In this method an advancing fire is controlled by deliberately starting a fire from the opposite direction. The two fires meet and burn each other out. Thus, a part of the forest may be sacrificed to counter firing thereby sparing the other areas. The steps are involved in this-

- a fire trace is cleared of all vegetation. Fire lines may also function as fire traces.
- dry leaves and shrubs are collected in the direction of the advancing fire and a counter fire started which is made to spread in the direction of the main fire. The direction of spread of the main fire has to be carefully controlled.

POST SUPPRESSION OPERATIONS

These are an important set of operations which have to carried out once the main fire has been put out. The post suppression operations consist of the following:

(i) All smouldering pieces of wood, stumps, twigs etc are completely put out.

(ii) Burning or smouldering trees are felled and removed from the forest.

(iii) The burnt area is surveyed and a map prepared showing the extent of the damage.

(iv) The loss is computed, cause of the fire ascertained and a final report about the fire submitted. Some state forest departments have made it mandatory to carry out a detailed investigation about each fire before the final report is filed.

(v) A detailed plan is prepared for rehabilitation of the burnt area through soil conservation and plantations.

CHAPTER 8

SHIFTING CULTIVATION

Shifting cultivation is a primitive form of crop growing prevalent in many parts of the world, particularly in the densely forested hills inhabited by tribals. This method of cultivation is very old and it is believed to have marked the change from food gathering to food growing. It has been retained by tribals living in areas receiving a large amount of precipitation thereby creating conditions favourable for a luxuriant growth of vegetation.

It is so named because cultivators do not use a particular patch of land year after year. A patch of land is selected and is steeped of all vegetation which is left to dry in the sun and then set on fire. The clearing thus obtained is taken up for cultivation. Seeds are sown either by dibbling small holes in the ground by means of a wooden stick or metal piece or they are broadcast. All operations are carried out by human labour and no plough or animal labour in used.

The FAO (1978) has described this form of cultivation as, "cultivation involving the removal and usually the burning of vegetation to create non-permanent clearings which are fallowed to bush or forest for varying lengths of time, but also includes the temporary removal of vegetation for pasturage or other purposes of livelihood".

Shifting cultivation is a major problem in India. In 1975, Vidyarthi estimated that about 2.6 million tribal people living in the interior hilly areas practiced shifting cultivation.

According to CSE report (1984-85) on India's environment, this form of cultivation was practised in about 228 development blocks falling within Arunachal Pradesh, Meghalaya, Mizoram, Nagaland, Manipur, Tripura, Assam and Orissa. It is adopted as a form of cultivation in areas having a total annual rainfall ranging from 250 cms to 1000 cms and on slopes

between an elevation of 1000 mts and 1200 mts. However, in certain parts of Arunachal Pradesh even areas upto an elevation of 2000 mts are being cultivated by this method. The density of population of areas under shifting cultivation is very low. In the past, this practice was also prevalent in some other states like Bihar, Madhya Pradesh, Karnataka, Kerala and Andhra Pradesh. However, slowly the tribals practising this baneful form of cultivation have been weaned away towards better methods of agriculture in these states.

Shifting cultivation has been named differently in various parts of India. It is known as *Jhum* in Assam; *Lo* in Mizoram; *Tekeonglu* in Nagaland; *Adiabik* in Arunachal Pradesh; *Rooduis momo* in Tripura; Bagada, Koman and Dahi in Orissa; *Panda. Bewar, Dipa* and *Datus* in Madhya Pradesh; *Watra* and *Walar* in Gujarat and S.E. Rajasthan; *Kumasi* or *Kumari* in the Western Ghats; *Khalla* or *Kurai* in Bhiar and *Podu* in Andhra Pradesh.

The areas which are under shifting cultivation are left to fallow after being cultivated for 2 or 3 years. Thereafter, these are taken up for cultivation again after a period of 18 to 20 years. The period for which a particular patch of land was fallowed was fairly long in the past but now paucity of land has brought this down to 10 to 12 years or even less.

One peculiarity of areas which have been under shifting cultivation is that the nutrients taken up by the crop are not replenished except by the ashes from the burnt debris that is left in the field. Thus, the crop yields from such areas begins to diminish from the second year onwards. It falls sharply after the third year and this forces the cultivators to move to a fresh patch of land. Soon, a vegetative cover reappears on this land, hekped largely by the heavy precipitation. The cultivator returns to this land after some years.

SCHEME OF OPERATIONS

In most areas of India, where this method of cultivation is still being followed, the land under shifting cultivation belongs to the tribe or community. However, when it is taken up for

cultivation, the cultivating family has full rights over it and this continues till the land in question remains under cultivation. After the land has been fallowed, the rights again vest with the tribe or community.

The scheme or pattern of operations followed for shifting cultivation in north-east India are :

(a) **Site Selection :** This is an important step in the scheme of shifting cultivation. The area to be cultivated is allotted to a household or family by a village council or headman. This is done well before the beginning of the sowing season.

(b) **Clearing :** The land is stripped of all vegetation including trees, shrubs and herbs. The debris is left tc dry in the sun. This operation is carried out in December and January.

(c) **Burning :** The material is left to dry in the sun for a period of upto 2 months. A good sunny day is selected for this purpose. The fire is prevented from spreading to the adjoining areas. The entire debris is burnt and the ashes are left in the field. It provides nutrients to the soil.

(d) **Dibbling and sowing :** Dibbling and sowing operations are taken up as soon as the rains begin. The seed is either dibbled into the soil by using wooden sticks or crude iron tools or they are simply broadcast over the entire area. The method of sowing depends on the crop that is being raised. Paddy is the most common crop in north-east India.

(e) **Weeding :** The new crop comes up after sometime, aided primarily by the heavy downpour that takes place for 3 to 4 months. This also brings about a heavy growth of weeds.

These weeds are removed manually 3 or 4 times during the entire cropping period.

(f) **Protection** : The tribals protect their crops from damage by wild animals, birds and from members of other tribes.

(g) **Harvesting** : The crop is ready to be harvested by mid-November or early December. This is done by using simple iron tools such as sickles.

(h) **Threshing and storing** : The harvested crop is kept in bundles. Threshing is done on a good sunny day by beating the stalks on a large stone, or by trampling or by beating with a stick. The grains are transported to the village and stored in large earthen pots.

(i) **Celebrations** : Merry making takes place after the crop has been harvested and stored.

MAIN CROPS

The main crops raised by shifting cultivators include both cash crops as well as cereal crops. Amongst the foodgrains, cereals and paddy are the principal crops. Others are maize, millet and jowar. The vegetables grown include pumpkins, cucumber, melons etc.

The following table give Jhum data for north-east. India (Source : ARE Centre, Jorhat, as cited by Negi 1982) :

Number of villages	2,973
Number of districts	5
Income from jhum as percentage of total income	70.2%
Number of households engaged in jhuming	90,457
Return per hectare	Rs. 693.35
Average size of households	4.98 persons
Annual man days required for each hectare	219
Area under jhum in each year	92,000 hectare

Average return per man day	Rs. 2.43
Percentage of area under jhum of geographical area	1.13%
Net area sown per year	70,000 hect.
Total population dependent on jhuming cultivation	270,000
Percentage of total population	57.69%
Number of tribal families engaged in jhum per 1000 ha.	148
Per capita income per year	Rs. 838
Literacy percentage	11.29
Density of population	6 persons per sq. km.
Consumption of fertilizer in kg. per hectare	
High schools, available per thousand persons	0.06
Hospitals available per thousand persons	0.02
Cattle per thousand persons	386
Buffaloes per thousand persons	20
Goats per thousand persons	151
Poultry per thousand persons	2,650

The following table gives the percentage distribution of contribution made by different occupations in the total village income of jhum areas (*Source :* Village Surveys, ARE Centre, Jorhat, as cited by Negi 1982):

Occupation	Khoura	Pakam
Jhuming	56.3	50.8
Settled cultivation	3.5	21.4
Horticulture	NA	5.2
Agriculture labour	-	-
Animal husbandry	0.6	2.1
Forest-based industries	13.6	2.0
Arts and crafts	NA	2.0
Trade and transport	-	-
Non-agriculture wages	5.4	13.7
Service/salary	11.8	4.8
Miscellaneous	8.8	-

BACK GROUND

As stated in the previous text, the practice of shifting cultivation is limited to the very high rainfall zone where the heavy precipitation compensates for the crude cropping practices that are adopted. It is evident that a number of factors have produced a typical set of conditions that have resulted in the people continuing with this form of cultivation.

1. Precipitation

The crested moon-shaped hills of north-east India face the open plains of Bangladesh with the Bay of Bengal further towards south. The moisture-laden clouds of the SW monsoons come directly in contact with mountains, thereby causing well distributed rainfall on the southern slopes of these hills. The vast amount of precipitation supports the crops raised by the shifting cultivators, irrespective of the method adopted by them.

2. Population Density

The density of population in the tract in which shifting cultivation is practised is very low. Thus, a vast tract of land is easily available to the tribals for carrying out shifting cultivation. Enough land is available to be kept fallow for a fairly long period. However, due to the increasing population pressure, the cycle of cultivation is slowly decreasing.

3. Terrain

In the lower hills the terrain is suited for the adoption of shifting cultivation. Except in the upper reaches of Arunachal Pradesh, the hills of north-east India. This is a permanent form of cultivation due to the low rolling hills and wetlands. Vast tracts of level land is not available for settled agriculture in areas where jhuming is prevalent.

4. Financial Inputs

Settled agriculture in the hilly areas needs a fairly heavy financial outlay for constructing terraces, laying out a system of drainage and for inputs such as improved seeds and fertilizers.

The tribals are too poor to be able to afford such heavy costs. Moreover, terracing is a time-consuming operation and the illiterate tribals do not seem to have enough patience for it.

5. Lack of Facilities for the Optimum Utilization of Water

Even though there is very heavy rainfall in this tract, the precipitation is not evenly distributed throughout the year. There are virtually no facilities for the optimum use of the vast resources of (rain) water that is available in this tract. It is difficult to impound and channelize this water so as to make it available when and where it is required.

6. Pattern of Land Ownership

The ownership pattern in the tract in which jhum is practised is as follows :

- The land is owned collectively by the villagers
- or the land is owned by a group of families and rarely by individual families
- or the land is owned by the tribal chiefs who distribute or allot the land for cultivation amongst the members of their tribe.

The headman or tribal chief plays an important role in the allotment of land. He may order his followers to move to new places. They do so at his bidding as these people still follow the primitive system of society.

7. Lack of Basic Needs

A small plot of land cannot yield enough to meet the cultivators' basic needs of food, clothing, tobacco, shelter and health care. This they provide by raising cash crops like tobacco, ginger, chillies and mustard intermixed with paddy in the field under jhuming cultivation.

8. Calamities

Calamities like death, sickness or natural diseases often force the people to abandon a particular area and move to a new tract. This is based primarily on superstition. Even though crop failures may occur due to the vagaries of nature, landslides and climatic conditions, these are often attributed to evil influences and superstitious reasons. This results in the people moving from one homestead to the other. Other calamities that force the tribals to abandon a particular area and move to a new tract, include frequent elephant raids, earthquakes or epidemics of plant diseases.

9. Crop Yields

Continuous cropping of a particular patch of land for a period of more than two years leads to a sharp fall in the yield. The jhum cultivators have neither the knowledge nor the resources to replenish or supplement the soil nutrients that have been depleted during plant growth. The yield after two years of continuous cropping declines sharply and this forces the cultivators to abandon that land for a temporary period and to take up another patch of land for cultivation.

SHIFTING CULTIVATIONS - A way of life

Shifting cultivation is a way of life for the tribes living in north-east India. Majumdar (1976) states that the Garo religion is nothing but a way to obtain bumper crops and to keep away disease and disaster. Thus, the operations connected with shifting cultivation are carried out in accordance with religion and religious practices in a series of annual rites that mark each stage of these operations.

Thanga (1982) has given an interesting set of religious festivals and rites that are linked to the different stages of the shifting cultivation cycle. He writes, "after allocation of plots for cultivation each family performs a religious rite on a plot, marked by dancing and singing. Burning and planting is marked by the *Agal makea* rites. The Nokma tribe (belonging to the (land owning

clams) performs the *Miamue* rite at the time of fruiting of rice plants. The lifting of taboo on certain plants and vegetable leads to the performing of *Rongchugala* and *Ahia* rites. A series of festivals and rites are celebrated and performed at the end of the harvest and close of one agricultural season. This is called *Gandwangala*. The entire community gets together and celebrates. The celebrations may go on for a considerable period of time...."

The calender of jhum operations regulates the social and cultural life of the tribes of north-east India. All festivals are celebrated after the completion of a stage or set of jhum operations. Social and religious activities such as marriages are arranged according to the timings of jhum operations. In the Siang district of Arunachal Pradesh, a newly married wife of the Padama tribe is brought to her husband's home only when the harvesting is over or is about to be completed.

In the recent past, these close linkages between religion and shifting cultivation are being broken under the influence of modern civilization and due to the efforts of a number of Christian missionaries. A number of tribes now take up jhuming merely as an occupation. They do celebrate there festivals but more according to the season than on the basis of the timing of different stages of shifting cultivation operations.

Succession

A peculiar succession occurs in an area which has been under shifting cultivation for the past 50 years or so. Bordoloi (1976) has reported that after a patch of land was burnt, nothing seemed to happen for the next two or three weeks. After this period, a few varieties of blue-green algae appeared. These include *Analeana, Chopsis, Cuthrix, Nostoe, Stichococus* and *Tolypothrix*. Their presence is significant as they multiply very fast under humid and optimum temperature conditions.

Jain *et al.*, (1976) observed the changes in the flora of an area under shifting cultivation. They have reported that after the tree cover has been removed many species forming a part of the

ground flora no longer find the habitat conditions suitable for their survival e.g. *Paphiopedilum farreanum* in Kameng and *Aeginetia indica* and *Balemophora dioica* in other areas.

Hajra (1975) has given a long list of plants which include trees, herbs, epiphytes and orchids which appear in an area under shifting cultivation. These include :

Ageratum conyzoides	*Cardamum hirsuta*
Chenopodium album	*Erigeron hirta*
E. thymifolia	*Eupatorium odoratum*
Euphorbia prostata	*Galinsoga parviflora*
Lumex sp.	*Mikemia nacarantha*
Oxalis corniculata	*Plastago major*
Spergula aroensis	*Spermaeoce*

When the land under shifting cultivation is abandoned, the vegetation gradually establishes itself with species like :

Erigaron sp.	*Eupatorium adenosperma*
Gynura angulosa	*Lantana camara*
Solanum sp.	

Perennial grasses gradually establish themselves, and in a short time, the tract is covered with a good ground flora which includes grasses, other herbs and shrubs. At higher elevations the abandoned lands are invaded by *Artemisia, Eagopyron* and *Rubus* while *Canabis, Gleichemia* and *Mikenia* come up on the lower slopes.

The main tree and large shrubby species with slowly come up in an area which has previously been under shifting cultivation in north-east India are :

Altingia excelsa	*Amoora wallichii*
Anplectrum assamica	*Bischofia javanica*
Bombax ceiba	*Calophyllum polyanthum*
Castanopsis indica	*Dipterocarpus alata*

Dipterocarpus macrocarpus	*Eurya acuminata*
Ficus sikkimensis	*Krema angustifolia*
Lagerstroemia sp.	*Phoebe cooperiana*
Rhododendron santapani	*Sauraiya roxburghii*
Syzygium cumini	*Syzygium fruticosum*
Syzygium mishimiensis	*Syzygium nepalensis*

The main herbs and grasses which come up in an area that has previously been under shifting cultivation in different parts of north-east India are : *Ainseiala, Anaphilis, Careamine, Dichrocephala, Eupatorium, Pteridium, Saccharum, Setaria, Themeda* etc.

ADVERSE EFFECTS

Shifting cultivation has adverse effects on the environment. The main environmental problems caused by this method of cultivation are :

1. **Reduction of forest area** : The practice of shifting cultivation has led to a reduction in the forest area, particularly at a time when the national efforts are towards increasing the total forest cover of the country.

2. **Loss of forest produce** : The cutting and burning of the vegetation leads to the loss of timber worth crores of rupees. This also results in the depletion of a potential source of raw material for forest based industries such as paper and pulp, plywood etc. It deprives the people of the area of a source of employment.

The local population is also deprived of a source of fuelwood, fodder and other forest produce which could be used for their day to day needs.

3. **Pressure on forests** : The shifting cultivators draw up heavily from the forest areas in the form of fuelwood, fodder,

timber and other forest produce. They even encroach upon forest areas.

4. **Accelerated erosion :** Degradation of the vegetative cover leads to accelerated erosion and other related problems such as depletion of nutrients from the soil; rill and gully erosion etc.

5. **Forest fires :** During burning operations, negligence on the part of the shifting cultivators may result in the fire spreading to the adjoining forest areas. Such fires destroy forest produce worth crores of rupees. Small fires may destroy seedlings upto the pole stage, shrubs, and may alter the status of the soil micro-bioecology. Forest fires also disturb the local wildlife by driving them away from the fire-affected areas.

6. **Siltation :** Shifting cultivation results in the increase of the silt load of the surface run off. This fills up reservoirs of multipurpose projects, chokes canals and deposits unsorted sediments over valuable arable lands.

7. **Misuse of land :** This method of cultivation amounts to the misuse of the valuable land. It is unfortunate that hundreds of square kilometers of good land is uselessly fallowed for a period of 10 to 15 years. Had this land been kept under continuous production it could have yielded thousands of tons of more foodgrains.

The rapid increase of population has brought about a severe pressure on the scarce land resources. As mentioned in the above text, this has forced the shifting cultivators to reduce the period for which the land is kept fallow from about 20-25 years in the past to 8-12 years at present.

8. **Local extinction of flora and fauna :** In many areas rare floral and faunal species may become locally extinct due to the repeated burning of the vegetative cover.

9. **Floods :** In north-east India the problem of floods during the monsoon season has become very acute. This is due

to the increase in the surface run off from areas under shifting cultivation.

CONTROL OF SHIFTING CULTIVATION

Chaturvedi and Uppal (1953). state, "... the correct approach to the problem of shifting cultivation lies in accepting it not as a social evil, but recognising it as a way of life, not condemning it as an evil way of life but regarding it as an agricultural practice evolved as a reflex to the physiographic characteristics of the land ...".

While taking up any measures for controlling this problem it must be borne in mind that in the eastern Himalaya, this method of cultivation is very deep-rooted and any drastic changes may prove to be counter-productive. At seminar the socio-economic problems of shifting cultivation were discussed in detail and a board-based solution was suggested. The following are the salient features of the proceedings of the seminar :

1. It was agreed that shifting cultivation in north-east India needs to be replaced by an improved and modern form of land management, keeping in view the need for conserving the environment. However any such step has to be in phases so that the change is gradual and the tribals have ample time to adjust to the new conditions.

2. Shifting cultivation is a way of life and is subject to change due to the rapidly changing conditions. However, the process and pace of this change should emanate from within the tribal society even though the role of state help in the form of technical guidance and know-how cannot be denied.

3. Care needs to be taken to initiate the requisite social and economic changes while improving

the way of lefe of the shifting cultivators so that there are no undesirable consequences.

4. it was suggested that a data base on the various aspects of this form of cultivation be created for projection of the overall picture and the suggestion of proper remedies.

5. Any change in the practice of shifting cultivation is bound to have a bearing on the forestry practices of the area.

6. The need was felt to analyse the possible effects of a change in the pattern of cultivation on the production of each crop including oil seeds.

7. It was agreed that horticulture is a suitable alternative to this method of cultivation. An infrastructure needs to be developed for raising fruit orchards and providing adequate marketing facilities.

8. The idea of terracing the land for settled cultivation was also discussed in detail but it was felt that as terracing is costly, it cannot be taken up on a large scale.

9. Immediate action should be taken to identify locations by use of aerial photo-interpretation techniques so that an integrated approach for the control of shifting cultivation can be tried.

10. There is a need to explore the scope of animal husbandry and raising plantation crops in the hilly areas.

11. As the switch over from shifting cultivation to settled cultivation is bound to take some time, it was suggested that studies should be taken up to improve the present techniques of shifting

cultivation so as to cause minimum soil erosion and loss of soil fertility.

12. The seminar made a strong plea for integrated research on the basic problems connected with shifting cultivation by scientists of all disciplines including social scientists.

The need for controlling the problem of shifting cultivation has been emphasised time and again. The National Forest Policy of 1894 states, ".... a) Honey combing of a valuable forest by patches of cultivation should not be allowed. b) Cultivation must be permanent and must not be allowed to an extent so as encroach upon minimum areas of forest that is needed to meet the reasonable forest requirements present and prospective ....."

The National Forest Policy of 1952 lays stress on "weaning the tribal people by persuasion, away from the baneful practice of shifting cultivation...."

While discussing the reappraisal of the National Forest Policy (1952) the estimates committee of the fourth Lok Sobha in its report stated, "in the matter of shifting cultivation besides introducing agro-silvicultural measures with the provision of necessary opportunities and facilities, steps should be taken to provide tribals with the alternative means of livelihood".

The National Commission on Agriculture report 1976 reads, "A large population of tribals live in and around forests. Considerable damage is caused to the forests by the wasteful practice of shifting cultivation. It is practised in the same area as long as soil fertility lasts to their satisfaction from 1 to 3 years at the most. In view of the limited forest area, the rotation is comparatively short. In the second rotation, fertility cannot build up to the original level and erosion also takes place. Increase in the tribal population is also responsible for the shortening cycle. With shortening rotations yield also gets poorer from one cycle to the next. As such, both from the point of view of the tribals themselves the wasteful practice of shifting cultivation should be

regulated, contained and replaced as expeditiously as possibly by resorting to agro-silvicultural methods apart from other methods. These should be explored, planned and implemented in cooperation with other concerned departments including the Tribal Welfare Department. As shifting cultivation is an age-old practice with the tribals, any programme to regulate shifting cultivation has to form part of the wider plan for tribal welfare."

The National Forest Policy 1988 states, "Shifting cultivation is affecting the environment and productivity of land adversely. Alternative avenues of income suitably harmonised with the right use and practices should be devised to discourage such cultivation within the area already affected by propagating improved agricultural practices. Area already damaged by such cultivation should be rehabilitated through social forestry and energy plantations...."

In its report the FAO/UNEPA (1975) Project states :

(a) "In order to quantify problems of shifting cultivation data at the lowest level (village level) must be available. The data can be compiled at regional level for regionalisation, e.g. in Mizoram, there was a system of collecting village reports annually, through the secretary of each village council. The secretary used to collect data from each household and used to submit it to the government each year. Data was available under the heads : No. of households, persons below 12 years, persons above 12 years, total persons, paddy seeds sown in tons etc. This could help in estimating the area under shifting cultivation even at village level, rate of production and population involved in it. This was maintained for each village for whole of Mizoram state. The same system can be introduced all over the country in regions where shifting cultivation in practised.

(b) The Pre-Investment Survey of Forest Resources, Dehra Dun and National Remote Sensing Agency, Secundrabad, or the National Atlas and Thematic Mapping Organisation, Calcutta, or the Survey of India, may be requested to extend their air survey and interpretation of aerial photographs in the affected areas of shifting cultivation, location and distribution of fields, nature of fallow land for recoupment of forest and cycle of recuperation at regional level.

(c) The problem of shifting cultivation should not be considered in isolation. The total situation of each region having homogeneity in problems, should be attempted to be solved through integrated area planning. The inter-relationship among various socio-economic activities depend a great deal on where they are located. If special relationships among existing activities are observed, it will be noticed that there is a definite pattern in the dispersal or concentration of activities in space.

(d) As this age-old practice of shifting cultivation is deeply rooted in the cultural life of the tribal people, it is desirable to know the cultural life of each community and reasons behind their tradition. This may be known only through the approach of insiders view."

The working group on `Tribal Development Programmes based on Forest' has made up important recommendations as given below :

(a) The existing rights and privileges of the people should not be abridged except where they are over-riding national considerations to do so.

(b) Forest settlement operations may be completed most expeditiously in all the forest areas so that the rights and privileges of the local people are officially recognised and codified.

(c) The problem of shifting cultivation needs to be tackled by multidisciplinary approach at different levels.

(d) There is great need to train forest officials particularly upto Rangers' level on tribal welfare policy and programmes to develop a sympathetic attitude towards the tribal people.

SHIFTING CULTIVATION AND TRIBAL DEVELOPMENT

During the period before independence, a two-pronged approach was adopted for developing the tribals living in various parts of India. These tribes were by and large engaged in shifting cultivation. They were totally isolated. The need was felt to bring the tribal population into the mainstream. Special provisions under the article 45 of the constitution of India, deal with the tribals of India. The Jhumland Regulation 1947 dealing with areas under shifting cultivation was passed in Assam. The Tribal Development Agency (TDA) or Special Multipurpose Tribal Development Blocks (SMTDB) were set up by the government of India of function in areas having a concentration of tribal population. Emphasis was laid on the development of the socio-economy of the tribals so as to wean them away from the practice of shifting cultivation.

Tribal development was stressed upon in the different five year plans. In the previous two five year plans, compact areas of tribal population were demarcated at the district, taluk and block levels. A care programme was drawn up for providing the basic infrastructure necessary for warehousing of produce; completion of medium and minor irrigation; provision of improved agriculture and horticulture practices; tackling of the problem of shifting cultivation; establishment of agro- and forest-based

industries; construction of roads and other communication facilities and strengthening of the administrative structure.

A sub-plan, within the state plan has been evolved to look after the task of tribal development. The salient features of this sub-plan are :

- to deal with the special needs of the tribal areas
- its resources are the sum total of the central assistance, state plan allocations of the sub-plan areas and institutional finance
- this concept allows for an integrated development of the tribal population. Three development zones were made :

(a) Zone of tribal concentration - having a tribal population of over 50 per cent of the entire population.

(b) Zone of dispersed tribal population - having a tribal population of less than fifty per cent

(c) Zone of isolated pockets of tribal population.

Special efforts were made to tackle the problem of shifting cultivation in all these three zones. A number of special programmes have been taken up for integrated tribal development and elimination of shifting cultivation. These include :

1. Small Farmers Development Agency

Under the SFDA programmes in areas under shifting cultivation the following schemes are carried out :

(a) The shifting cultivators are being provided with financial and technical assistance for terracing, contour bunding and soil conservation and other erosion control measures.

(b) Facilities are being provided for irrigation during the period when there is virtually no rainfall.

(c) The shifting cultivators are being encouraged to go in for horticulture and farm forestry.

2. State Sector Schemes

Some states of north-east India have taken up their own state sector schemes for tackling the problem of shifting cultivation. They were given lands to settle on and were provided with inputs to raise cash crops and rear pigs and poultry. An infrastructure has also been created for basic education and health in the areas where shifting cultivation is prevalent.

3. North East Council Programme

From the fifth plan onwards, the North-East Council has taken up the task of controlling shifting cultivation in the north-eastern region. The salient features of this programme are :

- terracing and contour bunding
- raising agriculture, fruit and cash crops on a more or less permanent basis
- improving shifting cultivation practices in areas where the problem is too deep-rooted to be eradicated.

Centrally Sponsored Pilot Project for Control of Shifting Cultivation

During 1976-77, the government of India launched 12 pilot projects for controlling shifting cultivation in Arunachal

Pradesh, Assam, Maghalaya, Tripura, Nagaland and Manipur. Under these projects, a 2-hectare plot of land per family was given to 100 families. Of these, one hectare was to be used for wet cultivation and the remaining one hectare for forestry, horticulture and the cultivation of cash crops. The project also provided certain basic facilities such as roads, drinking water, medical centres and schools.

In the beginning the scheme was to last for three years at a cost of Rs. 10.77 lakhs. However, later on, it was realised that this was too short a period for the cash crops and fruit plantations to give definite results. In view of this, the scheme was extended for a period of six years. It was found to be highly successful in Arunachal Pradesh.

The National Commission of Agriculture (1976) advocated the following approach for combining tribal development with the eradication of shifting cultivation practices. It states, "The main approach to the solution of the problem of shifting cultivation should be by permanently settling the shifting cultivators and weaning them away from the practice of shifting cultivation. Suitable areas in the lower reaches and valley lands and on gentle slopes should be terraced for settled cultivation. To bring about a change from shifting cultivation to settled cultivation, it is necessary to see that land formation is properly done and adequate investment is made for facilities like irrigation and inputs like seed, fertilizer etc. The guidelines of the NCA laid stress on the following points :

(a) Providing facilities for small scale irrigation from hill streams.

(b) Taking up extension education so as to make the people aware of the harmful effects of this method of cultivation.

(c) Terracing involves a high financial outlay and hence should be taken up only in cases where finances for the maintenance of this system are expected to be available for the next 10 to 15

years and institutional arrangements such as irrigation, seed and fertilizer are provided.

(d) The land tenure system needs to be corrected. A number of studies show that alienation of land owned by tribals takes place even in areas with good soil and irrigation facilities.

(e) Adequate restrictions may be placed on the use of the rights and concessions of the tribals in the collection of forest produce such as fuelwood, fodder and timber, particularly where the absence of such restrictions is likely to degrade the conditions of the forests.

5. Success of the Anchal Samitis

The efforts of the government of Arunachal Pradesh through its forest department for eradicating the menace of shifting cultivation are laudable. The forest department has started a scheme of taking over the village forests for their management after paying suitable compensation. The forest department secured 148 sq. kms of forest land of Namsang and Borduria tribes for a lease of 50 years through an agreement. According to the terms of the agreement, the net profit after deducting the expenditure incurred is divided between the tribal chief and the forest department in a 3 : 1 ratio. Seventy five per cent of the chief's share is submitted to a peoples Trust Fund operated jointly by the revenue and forest departments. The chief or village headman is paid the balance one fourth of his share subject to a maximum of Rs. 50,000. The rest of the money or profit is spent on welfare schemes such as the construction of roads, bridges, schools and hospitals and for advancing loans to needy persons. One residential boys school was started at Deomali in 1972 by the Rama Krishna Mission. The chiefs of Namsang donated about 250 acres of this land for the purpose. In 1973, the Rama Krishna Sarda Mission started a girls school and hostel at Khonsa. The local people were given loans to purchase shares or become members of a cooperative forest-based industry.

The creation of 'Anchal Samitis' in the latter half of the seventies is a significant success achieved by the government of Arunachal Pradesh. Thangam (1977) has described this programme in the following words, "The local people have shown a desire for willingly and actively participating in the development and creation of such forests which should bring substantial benefits to the community. The creation of Anchal forests would give them a sense of participation in preservation and protection of forests which would bring them handsome returns and also provide a basis for forest-based cooperative industries .... The Anchal Samities at Jand, Kameng district and at Tezu, Lohit district have placed certain forest areas for management as Anchal forests..."

In the end it must be stated that as shifting cultivation is the major occupation for the tribals living in north-east India, any programme for weaning away the people from this practice must provide for an alternative source of employment. In the recent past, the forest departments of some states have been able to utilize this labour potential in the form of taungya cultivation and for forestry works such as felling, transporting, nursery works and planting operations.

The approach towards solving this problem must take into consideration both the need to conserve the culture and the socio-economy of the tribal population. Thus, a programme aiming at the overall development of these areas is the best method of tackling shifting cultivation. (All references in this chapter are as cited in Environmental degradation and Crises in India, 1992 by Negi).

CHAPTER 9

ILLICIT FELLING AND ILLICIT REMOVAL OF FOREST PRODUCE

Illicit felling pertains to felling or cutting trees, illegally, that is without the required permission of the forest department. This may be from government or private forests or even lands on with only a few trees are standing irrespective of its ownership. Illicit removal of forest products means the extract of non-timber forest produce illegally. In India, the problem of illicit felling and illegal removal of forest produce is very serious in most areas. Regular gangs are operating in some regions, particularly where the cost of the forest produce involved is very high (e.g. sandalwood) forest officials are required to protect forests and trees against this menace which has contributed to degradation, deforestation and a closed loss of property.

Illicit felling is the illegal cutting down of trees of a forest. This may be carried out :

(a) By greedy persons who want to earn ill-gotten money.

(b) By villagers who do not have a valid permit of the D.F.O.

(c) By contractors who cut down unmarked trees.

Preventive Measures

Some preventive measures include :

(1) **Publicity**

In a democratic set up protection of forests will not be possible without the co-operation of the people. Hence, it is very

essential that a strong public opinion be built up against damage to forests. The effects of damage to forests can aptly be explained to the people by means of :

(a) Radio and television;

(b) Film shows, documentaries;

(c) Talks, lectures;

(d) Exhibitions;

(e) Demonstrations under stimulated conditions;

The following points should be explained :

(a) Environmental effects of damage to forests.

(b) Forests must be protected for their posterity.

(c) Illicit removal of forest produce amounts to theft. The people of India are by and large very religious minded and will not indulge in theft, once they know that illicit removal of forest produce amounts to a crime.

(d) Forests must be preserved if wildlife is to be preserved. Religious minded people abhor the destruction of wildlife and when it is explained to them that protected of forests are a must for the well being of wildlife, they will take up forest protection.

(2) Goodwill

After adequate and wide spread publicity has been done, goodwill of the people for forest protection will have to be enlisted. Such goodwill may be obtained in the following manner

(a) By quick disposal of legitimate cases of rights and concessions. Very often, the lower forest staff may take time to settle legitimate cases. Such delays should be avoided if goodwill is to be obtained.

(b) Quick supply of forest produce as per rights and concessions. Very often, the procedure for getting forest produce is so time consuming and cumbersome that villagers get frustrated. The local people have to run from one place to another, getting the reports of the entire lower hierarchy of the forest department, to get their legitimate supply of forest produce under the rights and concessions. This makes them feel very frustrated. At times, even right holders may resort to illicit removal of forest produce, because they do not want to go through the cumbersome procedures. Lazy forest guards and foresters add to their agony.

Thus, if the local forest staff wants to enlist goodwill of the people, it should ensure that legitimate supply of forest produce under rights and concessions is available to the villagers without much delay. Easy and quick legitimate supply of forest produce will generate a lot of goodwill between the local forest staff and the villagers and will also help to :

(i) Prevent illicit fellings;

(ii) Prevent illicit removal of minor forest produce;

(iii) Ensure that the villagers do not take vengeance on the local forest staff by setting fire to the forest, uprooting plantations or by letting in cattle into the forest.

Under the present conditions, villagers have to go to far off areas to get forest produce. Once they enter a forest, the villagers may damage trees, regeneration or may indulge in illicit

removal of forest produce. Hence, to save this and also to enlist the goodwill of the villagers, the following procedure is suggested :

(i) The forest produce should be extracted from the forest by the department.

(ii) It should be brought to a central depot.

(iii) For this depot, the forest produce (nistar) may be given to villagers as per their rights, concessions and needs.

The National Commission on Agriculture, 1976, has also advocated the setting up of nistar bhandar (or depots for forest produce required by villagers for their bonafide domestic and agricultural uses). It says, "We are of the view that in any case, the villagers should not be allowed to collect nistar themselves from the forests. Instead, nistar bhandars (depots) may be established at convenient places by the Forest Department for meeting the bonafide requirements of the people. For supply from nistar bhandars, a charge should be made, which should include the cost of production, transport, depot charges, as also a nominal profit".

Goodwill of the local people may also be earned if some other concessions are made to the villagers other than their bonafide rights and concessions.

Petty demands for :

(i) Construction of small bridges,

(ii) Repair of bridges, community halls, panchayat houses,

(iii) Miscellaneous causes of public interest, may be granted after suitable levy.

This would not only create goodwill but shall also put a check on illicit removal.

(c) **Meeting genuine demands** : A large number of cases of illicit fellings is an indicator that there exists a genuine demand for timber. Hence, opinions have been expressed that it is in the interest of the forest department that genuine demands should be satisfied. In cases, where villagers need firewood, for their domestic use and there is no fallen firewood, then these villagers will resort to illicit fellings. In such cases, it will be advisable to grant special concessions after the D.F.O. has ascertained the genuineness of the need.

In areas which are worked by contractors, the debris left over after felling operations have taken place, may be handed over to the villagers. The department may prevent the contractor from extracting the bark, small sized wood, chips etc. These may be given to villagers who are in genuine need of it. Thus creating the much needed goodwill.

The forest contractor should be asked to spare the medicinal plants in the form of climbers on trees. These can be handed over to the villagers. Thus it can be said that the root cause for illicit fellings and illicit removal of forest produce must be found out and steps taken to minimise these cases as far as possible. Such a step will be very helpful in generating goodwill. It may be kept in mind that in the absence of suitable and legitimate alternatives people take to illicit means.

Buying timber for their use from the open market is well within the reach of a few affluent amongst the villagers. However, timber markets are far off from their villages. It is a difficult and cumbersome task to get timber from far off places. Hence, these people take to illicit removal of timber. This can be checked by setting up timber markets near to the villages. Such an act will create an atmosphere of goodwill amongst the well off class of the villagers. These are the people who have considerable influence on the rural masses and they can be used as an instrument for checking illicit fellings and illicit removal of forest produce.

(d) **Forests as a means of economic upliftment :** Love for forests can be created in the villagers. This can be instrumental in creating a sense of protection amongst the villagers. Under the present conditions, most of the economic benefits from forests are derived by rich who live in far off places. By their capacity to invest large sums of money the people are employed as labourers and can barely earn their livelihood. Thus, there is a feeling with the local people that forests are meant for the good of the rich. This feeling has to be broken. In this direction, the following steps may be taken :

(i) Labour co-operatives may be set up and forest contracts given to them.

(ii) For this, the security deposit for such societies may be lowered. This will create employment opportunities for the local people and will generate a sense of goodwill.

(iii) Alternative employment : Alternative employment may be created for the local people:

(a) For all forest work, local labour should be employed.

(b) Local people should be trained for setting up forest based industries. They should be given loans for setting up such industries. This will create opportunity for employment and help to wean away the people from the baneful practice of illicit fellings. Some of the forest based cottage industries can include basket making, walking sticks, can works etc.

(c) Villagers should be trained in the recognition of medicinal plants. Thus they can collect medicinal plants from the

forest and earn their livelihood or at least supplement their incomes. Suitable marketing facilities for this need be created.

(d) The rural folk can be taught improved methods of poultry farming, animal husbandry, piggery, latest agricultural techniques, new crop varieties etc. This will improve their economic condition and will thereby keep them away from adopting illicit means to extract forest produce.

(iv) Intensive Patrolling : Illicit felling and illicit removal of forest produce can easily be minimised by bringing about intensive and regular patrolling in the forest. At present, the number of forest guards employed in patrolling is very less. Hence, their is a need for more guards. In areas where incidence of illicit felling and illicit removal of forest produce is more, a forest protection squad should be maintained. This squad can undertake checking in various areas.

Support of villagers should also be enlisted for this purpose. Villagers who give information about illicit fellings should be suitably rewarded.

Remedial measures

The remedial measures include :

(i) Prompt action should be taken against offenders under the Indian Forest Act.

(ii) All tools etc. used in the commission of the offence should be seized under the Indian Forest Act.

(iii) An offence report or damage report should be made.

(iv) The offender should be asked whether or not be agrees to the case being compounded.

(v) Or else the case should be presented before an authorised court.

(vi) For conviction, all evidence should be collected and such evidence be presented before the court as prescribed by the law.

CHAPTER 10

OTHER DAMAGES BY HUMAN BEINGS

Besides the adverse effects of human beings discussed in the previous chapters there are a number of other damages caused by human activities. These have been discussed in this chapter.

1. DEFECTIVE MANAGEMENT

Scientific management was introduced in India more than 130 years back. Since then all forest areas have been under planned scientific management. However inspite of the vast knowledge and experience of foresters of several generations, these cases of defective management have occured due to which immense harm has been caused to the forest ecosystem.

1. Errors in prescription:

Working plans are prepared for managing the forests on a long term basis. Inspite of a system of checks and balances at times a forest may be managed under the wrong silvicultural system. Examples of application of the wrong silvicultural system are the fir forests of Koti near Manali HP and the sal forests of the bhabar tract of UP

2. Errors in execution:

Inspite of the sound and scientific set of management practices prescribed in forest working plans there may be errors in their execution due to which long term damage is caused to the forest ecosystem. Some examples of lapses in execution are-

- faulty silvicultural markings
- neglect of regeneration areas
- allotment of wrong periodic block

Preventive and remedial measures:

The following preventive and remedial measures are adopted against the adverse effects of defective management:

(a) Widely experienced and dedicated officers are appointed for preparing working plans.

b) The working plans so prepared must be scientifically examined at various levels.

(c) Fellings should be linked to regeneration so as to rule out errors in prescription and execution.

(d) Due attention must be paid to subsidiary silvicultural operations.

(e) Periodic review of management must be carried out so as to detect any error as early as possible.

(f) Rehabilitation of forests damaged by defective management must be done on a priority basis. This could be done by plantings.

II. LOPPING

Lopping is the cutting of branches, twigs and leaves of trees for-

- fodder for cattle
- fuelwood
- for fencing material

Successive lopping year after year has an adverse effect on the physiology of the tree and they become prone to be attacked by insects and fungi. The production of fruit and seed is

also affected and such trees are liable to die off. Regeneration suffers as a result.

Lopping also has an adverse effect on the density and productivity of a forest. As a result there is less biomass production and the soil is prone to be eroded away at a faster rate.

In India many species are lopped for various purposes. In fact almost all main tree species are lopped depending upon the availability of better alternatives.

Lopping within a certain limit may not necessarily cause irreparable damage to the tree which is able to make up the loss within a short time. However excessive lopping is harmful. This is known as overlopping.

Preventive measures:

The following steps may be taken for protecting trees from damage by lopping.

(1) All working plans must prescribe detailed lopping rules for different species range wise.

(2) A four year cycle should be followed for lopping

(3) Lopping may be restricted only to the lower one-third part of the canopy of a tree. These should be no lopping in the upper two-thirds of the canopy. This prevents much damage to the foliage.

(4) No tree having a diameter of less than 30 cms should be lopped. Moreover, lopping of branches having a girth of less than 8 cms should not be allowed.

(5) There is also considerable damage to the tree from lopping tools. Trees should not be lopped

by axes and other heavy hand tools. This can be done only with light sickles having a blade length of upto 25 cms. Damage to trees can thus be minimised.

(6) It is advisable to avoid feeding cattle under a tree that is being lopped as there is considerable of fodder in this practice.

(7) There is strong need to build up public awareness about the adverse effects of lopping to trees and how this can be minimised. The publicity wing of the forest department and also the local forest staff can play a leading role in this direction.

Remedial measures:

The remedial measures that may be adopted are:

(a) In those areas where well growing trees have been damaged by repeated lopping fast growing fodder species may be planted. This will help to reduce the pressure on the trees of the favoured species and enough fodder will be available for stall feeding the cattle and for meeting the fuel requirements.

(b) An area may have to be closed to lopping for a period of 10 to 15 years if the damage is severe so as to allow it to fully recover its growth vigour.

III. LEAF LITTER REMOVAL FROM THE FOREST FLOOR

In many parts of the country particularly in hills there is a practice of removing the leaf litter lying on the forest floor for the following purposes:

(1) The leaf litter from the forest floor is partially decomposed in huge pits and spread over agricultural fields as manure.

(2) It is used for spreading under cattle in cowsheds so as to provide warmth.

(3) The pine needle litter is used as packing material for packing apples in the hills.

Adverse effects:

The adverse effects or disadvantage of this practice are-

(a) The leaf litter brings about changes for the better in the physical properties of the soil, such as soil structure and texture. This does not occur when the leaf litter is removed thus adversely affecting the physical properties of the soil.

(b) Leaf litter has a protective influence on the soil. It also acts as a cushion against grazing resulting in soil compaction. Soil without leaf litter is readily affected by the hooves of animals which in turn gives rise to serious environmental problems such as accelerated erosion and floods.

(c) The hydrological cycle is also maintained by the leaf litter. A thick cover of litter over the soil helps it to absorb water as it acts as a gaint sponge. In areas where the soil is devoid of the protective cover of leaf litter, a large part of rain water is lost thus leading to a fall in the water table and creating conditions of drought.

Protective and remedial measures:

The following protective and remedial measures may be adopted:

(1) This practice may be discouraged with the people being provided alternatives.

(2) Creation of awareness amongst the masses about the ill effects of this practice.

(3) Closure of all areas where excessive removal of leaf litter has taken place to grazing and lopping.

IV. COLLECTION OF FLOWERS AND FRUITS

In many forest areas the local people including tribals collect flowers and fruits of trees and shrubs for food, decorative purposes and edible oils. In fact these are sold commercially. One example is the large scale chilgoza pine seed collected from the forests of Kinnaur in HP and sold in faraway places.

These activities have an adverse effect on the regeneration of the forest and may create a shortage of seeds particularly with respect to those species which have good seed years after intervals of more than 3 years or even more.

Preventive and remedial measures:

The preventive and remedial measures against this form of damage include:

(1) Fixing a cycle during which flowers and fruits may be removed from a forest. There must be a closed period when such removals are not allowed.

(2) No removals of this kind should be permitted in PBI and PBII areas

(3) Rehabilitation of severely degraded areas must be done on urgent basis.

V. MINING OR QUARRYING

Nature has endowed India with rich mineral resources and in view of the large scale industrialisation programme, a rapid and massive exploitation of minerals is being carried out.

Amongst the two main methods of mining, quarrying or surface mining is the most damaging to the forest ecosystem as the exploitation processes like excavation, extraction and transport has to be done after clearing the vegetation occurring on the surface of the mine site.

Adverse effects:

The principal adverse effects caused to trees and the forest ecosystem are outlined below:

(1) **Loss of valuable land** : Valuable land is lost as the vegetative cover is removed. This land could have been put to other uses such as forestry, agriculture or pasture. Thus for all practical purposes this land is lost for all times to come.

(2) **Loss of forests** : The valuable forests growing on the land which is diverted for quarrying are lost even though a part of the capital may be recovered selling the trees that are felled during operations for clearing the quarry site.

(3) **Disturbance to forests and wildlife** : The whole forest ecosystem in the areas around the mining site is disturbed. Mining activities also have an adverse effect on wild animals and their habitat. There may also be poaching of wild animals by the labourers working at the mines.

(4) **Loss of productive top soil** : Nature takes thousands of years to produce a few centimeters of soil which is the basis of all kinds of vegetation. This is lost within the span of a few hours when the over-burden is stripped during open cast mining. This valuable topsoil is lost for all times to come and cannot be replaced by any method known to mankind.

(5) **Hydrological problems :**

(a) there is a general lowering of the watertable. Due to reduction of the forest cover, loss of valuable topsoil and exposure of bare rock during quarrying, there is less seepage of water into the surface. As a result the local watertable is lowered.

(b) Devoid of the protective cover provided by trees, shrubs, herbs and the top soil, the exposed rocks are subjected to the full action of the rainwater. This increases erosion both at the quarry site and in the downstream areas.

(6) **Mineral transport** : Roads are constructed right upto the quarry so that trucks and dumpers can drive right upto the quarry face from where the mineral is being extracted. Road construction damages the forest vegetation of the surrounding tract, soil cover and also results in debris slides.

(7) **Sediment inflow** : Quarries cause a large quantity of sediment to flow with the surface run-off. The erosive capacity of the sediment bearing run-off is greatly enhanced and this leads to the formation of rills and gullies in the forest and other lands lying downstream of the quarry site.

(8) **Debris slides** : The debris released during mining is thrown or carelessly dumped down the hill slope thereby causing the following adverse effects-

- formation of debris slides

- the debris covers forests, grasslands, fields, roads and even human settlements

- there is an increase in the load of the surface run-off.

(9) **Aesthetic loss** : Ugly looking repulsive scars formed by quarrying are an unpleasant site.

Preventive and remedial measures:

The following preventive and remedial measures may be taken for protecting forests and the ecosystem from the adverse effects of mining or quarrying:

(1) Quarrying leases should not be granted in densely forested areas. In any case the clearance of the forest department has now been made mandatory for grant of quarrying leases in most states.

(2) Roads for extraction and the elevation of the benches formed for quarrying may be planned only after taking into account the following parameters-

- natural ecosystem and its status

- slope conditions and nature of the terrain

- depth of the soil

(3) The area of the quarry should be as less as possible.

(4) A zone of no blasting to be observed in ecologically sensitive areas.

(5) The excavation debris should be dumped in safe and stable areas away from forests, grasslands, fields, roads, canals and human settlements instead of it being thrown haphazardly.

(6) Strips of forests or plantations should be maintained between two quarries.

(7) Use of ropeways and conveyor belts for transporting the mineral from the quarry should be encouraged.

8) The excavation debris at the quarry site may be graded or bunded. This helps in checking soil erosion.

(9) The overburden may be filled back into the quarry site once the quarry has been closed down.

(10) Reforestation of the abandoned quarry site should be made compulsory for all quarries. However it is very difficult to do so due to the following reasons -

- the soil cover is virtually lost and new soil may have to be brought in from outside.
- little or no nutrients are available to the plants
- there may be a continuously burning underground fire in case of abandoned lignite or coal mines

In recent times a number of techniques have been developed for reclamation of mined areas.

(11) Alternate mining methods such as underground mining which are less damaging may be adopted

even though the costs involved are higher than in quarrying.

(12) Creation of awareness regarding the adverse effects of mining both amongst the miners and also the general public is a must for helping to minimise damage from these ventures.

CHAPTER 11

SOIL DEGRADATION AND CONSERVATION

Amongst natures countless gifts to man, none is more essential for the survival of human life than soil. The upper layer of soil is the feeding zone of the plants that provide food for human and/or animal consumption; fibre for clothing and timber for shelter. The soil forms the very basis for the existence of the human civilization.

Water, wind or gravity results in the displacement of soil particles, their transport and subsequent deposition. In a natural, undisturbed environment, the dense vegetative cover protects the soil and retards its erosion to a pace which is almost equal to that of soil formation in the layers below. The slow removal of topsoil under undisturbed conditions is known as normal or natural or geological erosion. It is a normal phenomena which erodes the soil at one place and builds it up at another. The present day landforms have largely been formed due to this form of erosion.

However, when the surface looses its protective cover the soil is exposed directly to the abrasive (erosive) action of geological agencies. The rate or erosion goes up abruptly and the soil may be removed many times faster than normal. This process is known as accelerated or soil erosion.

Accelerated erosion is not a recent phenomena. It probably began when man first began to grow food and it has been continuing ever since. It has gained momentum whenever man's efforts to gain a livelihood from the soil have forced him to remove the natural protective cover of the vegetation. Many ancient civilizations have been wiped away due to this menace.

ADVERSE EFFECTS OF SOIL EROSION

Accelerated erosion is a major threat not only to the agricultural economy of the country but also to the well being of the entire nation. It is a cancer that is growing silently and one day

may severe the life line of our country. Soil erosion is very difficult to control, except in the initial stages. The following are the adverse effects of soil erosion :

1. Changes in climatic conditions :

Progressive soil erosion has a profound effect in changes in the response of land to plant growth and thence to climatic changes. This is a very conspicuous effect of accelerated erosion. Soil erosion leads to the washing away of the productive topsoil from a particular layer and the infertile subsoil is exposed. Plant growth, if any, is now forced to grow on this layer of soil which may present an entirely sew wet of growing environment. This results in a situation wherein the vegetative growth begins to fade out and with the disappearance of vegetation, drastic changes occur in the local climate.

The most obvious effect of the loss of vegetation due to soil erosion is the variation in diurnal temperature. The average maximum temperature rises whereas the average minimum temperature falls to below levels which were previously experienced. This is primarily due to the absence of the moderating physical and physiological effect of vegetation.

The disappearance of vegetation due to soil erosion also brings about a drop in the local relative humidity and precipitation. The absence of transpiration carried out by the leaves lowers the relative humidity. There is an increase in the direct evaporation of moisture from the soil during the afternoon when the heat of the sun is at its peak. Scientists believe that a loss of vegetation leads to an increase in their prographical effect to a variable but significant extent by causing precipitation through the condensation of moisture in the form of dew and mist and to a measurable extent by bringing about rain in the form of afternoon showers.

Thus, soil erosion causes certain significant changes in the local climatic conditions such as increasing the extremes of maximum and minimum temperature; lowering relative humidity;

an increase in the evaporation from the soil devoid of vegetation and a fall in the local precipitation.

2. Degradation of agricultural lands :

The fertile, rich and valuable topsoil is quickly washed or blown away by the effect of water or wing. The hard, infertile sub soil is exposed. Soil erosion has a profound effect on the degradation of agricultural land. This adverse impact is brought about in two ways :

(a) **Erosion of top soil :** The fertile topsoil is blown or washed away and it is not possible to raise crops on the poor subsoil which is lying beneath. This causes a drop in the agricultural production in the locality or region where soil erosion is taking place. The eroded lands have to be abandoned as after a few years of soil erosion, these lands are unfit even for the production of fodder.

(b) **Deposition on topsoil :** Material transported by wind and water from elsewhere is deposited over the productive topsoil which is thus rendered useless. In the valley areas, rock and soil eroded from the uplands is brought by running water and deposited over fertile agricultural fields. In arid areas, sand may be blown from the adjoining areas into agricultural fields.

The fine soil moving with the wind covers plant life and eliminates the chances of a good harvest. Moving sand dunes tend to cover the fertile fields and render them useless. The abrasive action of the moving sand may be so high that plants are sheared just above the ground level.

3. Degradation of forests :

Accelerated erosion leads to a gradual disappearance of vegetation from that area. However, on the other hand, the degradation of the forest cover may cause and sustain accelerated erosion. Thus, soil erosion and degradation of forests act as complimentary forces. They act from opposite directions and lead to the gradual disappearance of forests from a

particular area. Soil erosion causes the following adverse effects on the forest vegetation.

- There is a progressive loss of the favoured species and slowly unwanted tree species come up, which in turn disappear after sometime
- regeneration of the favoured species becomes difficult
- the existing forest ecosystem, may be disturbed and a retrogressive succession starts. The existing wildlife is forced to migrate to other areas.

4. **Fuelwood and fodder scarcity :**

Soil erosion brings about a shortage of fuelwood and fodder in the adjoining tracts. With the degradation and ultimate destruction of the forest cover an important source of fuel and fodder is lost. The village pasture lands are thus put to an extraburden to produce more forage. Fuelwood has to be obtained from the trees and shrubs growing on the periphery of agricultural fields. There may occur a condition in which even these fields and pastures are subject to erosion. This may force the inhabitants to abondon the village and tc settle down elsewhere as their economic condition is so poor that they are unable to purchase fuel and fodder from elsewhere.

A dradual drop in the availability of fodder sets off a process in which milk production falls and the beasts of burden become so weak that deep ploughing is not possible. A drop in milk production leads to a fall in the nutrition level of the inhabitants which is an open invitation to diseases. On the other hand, weak beasts of burden mean a shortage in the production of food.

5. **Drop in water supply :**

Accelerated or soil erosion creates conditions in which bulk of the precipitation drains away as surface run off and very

little water seeps into the soil. Thus there is a reduction in the underground water that feeds the springs and streams all round the year and many streams become seasonal in nature. They are dry for most parts of the year and water flows in them only during the monsoon season.

This adversely affects the quantity of water flowing into the major river systems and sets off a chain reaction that hampers economic activity such as :

- drop in hydro-electric generation
- shortage of water for agricultural production and for forestry operations.
- lack of water for drinking, cooking and washing in the villages lying below the eroded areas.
- shortage of water for industrial, urban and semi-urban consumption.

6. **Increase in floods :**

The role of a dense vegetative cover in regulating the levels of erosion has already been discussed. The rain drops fall on leaves in the uppermost canopy and then reach the top soil at highly reduced velocities. Thus they are rendered harmless. Once the raindrops reach the forest floor, the thick layer of humus in various stages of decay acts as a sponge and the water infiltrates into the soil. However, things change once this cycle is broken.

The raindrops strike the unprotected topsoil in the absence of a vegetative cover. This causes a considerable quantity of soil to flow away with the surface run off. The rivers are unable to cope with the huge quantity of silt which flows into them with the water from the mountains in the eroded uplands. Thus, the water overflows the river banks and inundates a vast area.

Floods occurs during periods of heavy rains each year as the unprotected soil is unable to absorb the water that comes down within a short span of time. The resulting floods destroy life and property worth crores of rupees each year. They inundate human settlements and infertile rock and soil is deposited over the fertile lands occurring along the river banks in the plains.

Swampy conditions are created by floods in areas where the gradient of the river becomes more or less level. Floods also cause considerable loss by delays caused in important agricultural activities including the marketing of farm produce; they cause damage to standing crops; livestocks; fences and impede the movement of farm machinery.

7. **Damage to water bodies :**

Water bodies such a reservoirs, lakes, rivers, irrigation canals, waterways and harbours are very essential for the well being of our civilisation. However they are severely damaged by accelerated erosion. The damage is usually in the form of siltation caused by the deposition of material eroded from elsewhere. Soil erosion thus causes damage to reservoirs, lakes, rivers, canals, waterways and harbours and puts a strain on scarce resources for repair or replacing the damage.

(a) **Reservoirs and lakes :** A large number of multi-purpose river valley projects have come up in different parts of India. These involve the impounding of water in lakes and reservoirs by daming the flow of rivers and streams. This water is used to generate electricity and is channelised to provide water for irrigation. However, due to an increase in the inflow of sediment into these lakes and reservoirs, their expected life span is rapidly going down. Studies show that the expected life span of most multi-purpose river valley projects in India has gone down primarily due to the increase in sediment flowing into the lakes and reservoirs.

(b) **Irrigation canals :** Erosion also seriously affects irrigation canals leading water to fields, orchards and nurseries. These adverse effects may be due to :

- frequent changes in the course of rivers and streams feeding the canals
- meagre water supply in the dry season
- choking or silting up of the canals due to the load brought down by the surface run off.
- breaching of canals in the hills brought about by slope failure.

Whenever a river changes its couse due to the vast quantity of debris brought down by the run off, the irrigation head from where the canals starts may be dried up. A large amount has to be spent on making channels to drivert the water once again to the headworks of the canal network before regular and effective irrigation is taken up again.

River and streams may become seasonal in nature. They remain dry for most parts of the year; there is no seepage into the soil and most of the rainwater falling in the uplands is lost in the from of surface runoff. The canals being fed by these rivers and streams are rendered useless unless arrangements are made to ensure a regular water supply all round the year. This is usually done by impounding the water during the rainy season and releasing it slowly during the dry period. Small dams are constructed across the flow of these rivers and streams.

The eroded material being brought down by the river and streams may be deposited in the canals which are choked as a result. A large sum of money has to be spent to repair the damage. Clogged canals also tend to overflow their banks and flood the adjoining areas.

The construction of canals in mountainous areas also causes problems related to soil erosion. The vegetation is removed and the canal is excavated. The debris released during this excavation work is allowed to roll down the hillside. It damages roads, agricultural fields, pastures, forests lands and

even human habitation. Whenever a canal is breached in the hilly area, a vast area lying on the slopes below it, is damaged by the resulting floods.

(c) **Waterways and harbours :** Inland waterways and harbours are an important means of communication. An increase in the load of the rivers and streams tends to choke the inland waterways and harbours, thus hampering the free movements of people and goods. Extensive dredging operations have to be taken up to repair the damage.

8. Damage to hydel projects :

Soil erosion and deposition causes damage to projects set up for the generation of power by using water. This may be brought about in the following manner :

- silt and sand in the water passing through the generator, tends to damage it. The generator has to be shut down and the damage rectified at a fairly high cost.
- a fall in the volume of water flowing down the streams leads to a drop in the production of power from that hydel project. Thus the demand for electricity cannot be met and new projects have to be taken up.

9. Adverse effect on communications :

Communication links such as roads and rail lines are the back bone of our economy. These networks are constructed at considerable costs. Soil erosion, transportation and deposition may cause severe damage to these communication links.

- roads and rail lines are washed away during floods.
- silt, sand and rock debris brought down by rivers and streams from the uplands is deposited over roads and rail lines.

- landslides cause heavy damage to roads and rail lines.
- telephone and telegraph lines are severely damaged.

A large amount of money, time, energy and labour has to be diverted to repair the above damage and to ensure the free movement of people and goods.

10. Adverse impact on public health :

Soil erosion has the following direct and indirect adverse effect on public health :

- deposition of debris may lead to the formation of swamps and ponds. These are breeding grounds of malarial mosquitoes and other diseases.
- a number of diseases break out in the aftermath of floods.
- winds carrying a huge quantity of dust tend to cause pulmonary diseases in people living in the arid and semi arid areas.

11. Other social an economic effects :

Soil erosion has a profound impact on the social and economic structure of the entire nation. The following are some of these effects:

- the productivity of the land goes down drastically and this has a bearing on the total output of foodgrains in the country.
- the income of the farmer drops and as a result there is a fall in his buying power which adversely reflects on the national consumption pattern.

- severely gullied lands can no longer be cultivated and these have to be abandoned. New lands are cleared and brought under cultivation. Thus valuable land resources are squandered, Farm abandonment and community migration puts a strain on the local and regional economy.

- floods and related problems cause widespread misery. The government has to spend crores of rupees each year to bring relief to the affected people. This places a heavy burden on the exchequer and diverts resources that are needed elsewhere.

- soil erosion also damages local industries such as fisheries, quarrying, tourism, tea, fruit production etc.

OTHER CAUSES OF SOIL DEGRADATION

Soil erosion and related phenomena is the major cause of soil degradation. However, there are other causes of soil deterioration. These are :

1. Deposition

A considerable quantity of soil and rock is brought down by the river each year. This includes the topsoil and parts of the infertile subsoil. When these rivers and streams enter the plains there is a drop in their velocity and this brings about the deposition of the load they are carrying. This material may be deposited over agricultural fields, pastures, forest lands and even human settlements. The period for which these fields are rendered useless depends upon the following :

- the thickness of the deposit

- the nature and composition of the material that has been deposited.

- subsequent depositions, if any. If deposition occurs in an endless cycle, then the land may never be brought back to normal productive use.

The seasonal streams emanating from the lower Siwalik hills of the western Himalaya are classic examples of the damage caused by deposition of unsorted material. These are known as choe streams in H.P., raus in Dehra Dun area and sot's into foothills of Kumaun. (Negi 1982), "These are terrace sediments which have been deposited by streams locally called 'choes' .... These sediments are thought to have been deposited by seasonal, ephermeral and intermittent flow, during the past 5 million years or so .... Each year the area affected by choes is increasing. This has been brought out in the following table :

1881	195.2 sq. km.
1884	324.1 sq. km.
1897	381.5 sq. km.
1936	607.3 sq. km.
1985	930.5 sq. km.

During the rainy season flash floods occur in these choes. This leads to the deposition of a large quantity of debris on agricultural lands and forests.

2. Depletion of plant nutrients

Plant nutrients are very essential for the production of agricultural, horticultural and forests crops. A progressive depletion of plant nutrients leads to a corresponding loss of *soil stability*. The depletion of plant nutrients from the soil may take place in the following manner :

(a) **Leaching** : Water is responsible for leaching away important nutrients from the soil. Potassium calcium, magnesium

and sulphur are amongst the important nutrients which are leached from the topsoil.

(b) **Over-cropping** : Repeated cropping without adding to the plant nutrients in the soil leads to their progressive depletion. This brings about an appreciable drop in the production of foodgrains.

3. Overgrazing

This is responsible for the deterioration of the soil. Valuable grasses disappear from the pasture or forest; the soil is exposed; and soil aeration is reduced due to the weight of the animals. These combine to cause the degradation of the soil.

4. Accumulation of toxic salts

Accumulation of toxic salts also leads to the degradation of the soil and thus to a drop in its productivity. Saline and alkali soils contain toxic soils that are harmful for crop production. Saline soils contain an excess of soluble salts which have concentrated in the soil. This causes a very high osmotic pressure in the soil solution and creates a condition in which water is not readily available to the plants and they die.

Alkali soils contain extra quantities of exchangeable sodium. This leads to a deterioration of the physical condition of the soil by deflocculation. The soil becomes impervious to water and plants are unable to grow on it.

5. Improper cultivation

Faulty and improper cultivation also causes the progressive degradation of the soil. The fertility of the soil remains at an optimum level if regular doses of manures and fertilizers are added to it. In the absence of this, regular cultivation gradually brings down the level of nutrients present in the soil.

Non-adoption of soil and water conservation measures while cultivating the land also lead to their degradation.

6. Waterlogging

Conditions of water logging are unfit for normal cultivation. Alternate wetting and drying cracks the soil and renders it prone to be washed away. A high concentration of toxic salts may accumulate on or near the surface due to water logging. An excess of moisture adversely affects soil aeration. Under these conditions, the soil is unable to support an adequate cover of vegetation and accelerated erosion takes place.

BUNDING, TERRACING AND DIVERSIONS

Bunding, terracing and diversions are three sets of mechanical measures which are very widely adopted for the conservation of soil and water. These are very widely adopted in forestry and allied operations under the following conditions:

- in areas where forest nurseries have to be set up
- in areas where tree plantations are proposed to be raised
- in pasture lands
- in wastelands whose condition is to be improved
- in areas where agricultural crops are to be raised in combination with tree plantations.

A **bund** reduces the length of a slope whereas a **terrace** reduces both the degree and length of the slope. Diversions are used to safely divert the water from a gently sloping land to a natural channel so as to minimise the damage caused by it.

BUNDS

Bunds are of the following types :

(a) Contour bunds

A contour bund is a small narrow earthen structure formed at suitable lengths along the slope so as to reduce soil erosion and to permit more infiltration into the soil. It is formed along the contours and hence the name *contour bunds*. These are also referred to as ridge type terraces or absorptive type terraces in other parts of the world.

Contour bunds are useful for lands having a slope of about 10 degrees. It may be done in areas having a rainfall of less than 250 cms each year. In very high rainfall areas, the bund may be washed away by the surface run off and other structures have to be constructed to retain the water and to prevent if from eroding the soil.

The spacing of contour bunds is done in a way that the water is intercepted before it attains a velocity that will enable it to cause severe erosion. This depends upon the following factors :

- the average slope
- soil conditions; erodibility and permeability
- amount and intensity of rainfall
- package of conservation measures that have already been adopted
- the use to which the land will be put

(b) Side bunds

The contour bunds are open and end either in a natural waterway or in side bunds which are constructed along the slope specifically for this purpose. Thus side bunds help to impound water within the contour bunds. An arrangement may be made for the removal of excess water from the side bunds.

(c) Lateral bunds

These are small bunds formed along the slope to restrict the water impounded by contour bunds having a length of over

300 mts to small compartments. Hence lateral bunds are constructed only in cases where the length of the contour bunds is more than 300 mts.

This has the following advantages :

- the water is restricted to small compartments so that the damage is restricted in case of a breach.
- the excess water can easily be diverted to the surplusing arrangement.
- it helps to spread the impounded water over a large area.

(d) Marginal bunds

In cases where contours are formed in the upper part of a land area and the lower part remains, a small bund is formed along the lower boundary irrespective of the alignment of the contour. This is known as the marginal bund.

Surplusing arrangements

Contour bunds act as obstacles for the flow of water and hence a small quantity of water is impounded by them. A part of this impounded water seeps into the soil but the rest of it has to be safely diverted to natural waterways where it will not cause damage. This is known as the surplusing arrangement and may be brought about in the following ways:

- the contour bunds are designed in a way that they open in natural channels.
- suitable openings are provided in side bunds so that the surplus water is led away.
- the channel into which the surplus water is diverted should have a grass cover or should be suitably paved.

TERRACES

Terracing is a system of systematic interception of the run off by the grading of slopes. It is adopted for soil and water conservation measures on slopes that are over 10 per cent. Present day methods of terracing have evolved after many years of field study and experimentation. Terraces are the most effective tool for erosion control measures if they are adequately and scientifically constructed. However, they may result in a higher rate of soil erosion if improper and faulty construction takes place. The design and construction of a terrace should suit the needs of the land being protected; local soil conditions, slope, drainage, time and expertise that is available.

The broad outlines of terrace planning and construction as adopted in forestry have been dealt with in the following text. The proper use of the land is the main consideration while devising ways and means to conserve the soil and water. It is essential to undertake a survey of the land capability classification of the land to be treated before deciding as to which lands are to be treated by terracing alone and where a combination of terraces and other measures are required. Land from which the soil loss cannot be adequately controlled by adoption of vegetative measures is to be terraced.

In forestry and allied operations, terracing is required to be done on land needed for the following purposes :

- for the setting up of permanent and temporary forest nurseries in hilly area.
- for the rehabilitation of wastelands.
- for steeply sloping land on which plantation are to be raised in the near future.
- for land intended to be used for raising agricultural crops in between rows of trees.
- for pastures.

Where the land is severely depleted, terraces are constructed for aiding the establishment of a good and permanent cover of grass. On such lands, terraces are constructed as a temporary measure. Thus, their design may be inferior to the one that is used for the construction of terrace on arable land on a permanent basis. The cost of construction of terraces on degraded land is more because of the following reasons :

(i) the steep slope.

(ii) relatively higher rates of erosion.

(iii) unsatisfactory, soil working conditions.

(iv) difficult topographic conditions; presence of rills and small gullies for which extra measures must be adopted.

(v) absence of a vegetative cover.

The ability of a system of terraces to conserve the soil and water depends upon the factors mentioned below :

(a) proper design and construction

(b) proper maintenance

(c) proper management practices.

The method of soil working is an important factor so far as terracing is concerned. Soil working should invariably be done for

- a satisfactory channel capacity
- channel and ridge side slopes should be moderate enough to permit the easy movement of machinery

- an economical cost of construction of the terrace should be maintained

- a larger cross section is needed for longer terraces.

DIVERSIONS

These are specially designed channels constructed across the slope of a land for intercepting the surface run off and conducting it to a safe outlet.

The main objects of diversion are :

- to reduce the length of the slope

- to divert water away from rills and gullies

- to divert water away from forest nurseries, roads and buildings.

- to protect the bottom land from overflow.

- to cut off the head water coming into the top terrace in cases where the land lying above cannot be treated by other means due to adverse topographic conditions or reasons of ownership.

Locating, designing and constructing diversion

The following are the salient features along which diversions are laid out, designed and constructed :

1. The catchment area of a diversion must be protected by a suitable cover of vegetation in the absence of which large quantities of soil will fill the channel.

2. Diversions should be used as a measure to control erosion in areas which need terracing.

3. Diversions should be located a little above the head of a gully so that a small strip of land remains in between the two.

4. These may be so located that the outlet water is safely led away and it is not able to attain very high velocities.

5. The best time to construct diversions is when the vegetative cover on the watershed is mainly grass. This will ensure that the run off and channel silting is at its minimum.

6. A uniform grade should be maintained throughout the diversion though the grade may be reduced on the upstream side.

7. The size of the channel should be calculated on basis of the maximum expected run off during the life of the diversion; the effectiveness of the vegetative cover in the catchment and soil conditions in relation to the safe velocity for different soils.

8. The diversion should itself be protected from the erosive capacity of the water it is conducting.

PREVENTION AND CONTROL OF GULLIES

Gullies are largely indicative of a functional disorder of the land. It denotes an improper use of the land over long periods. However, gullies are by no means the first symptoms of faulty management of the land resources. Flowing water removes the thin layers of the highly fertile topsoil much before the appearance of gullies. The formation of gullies is an end product of the process of accelerated erosion which usually has its humble beginnings in splash erosion. Hence, the appearance of

gullies is a secondary symptom and a trained observer should be able to spot the disorder of the land long before gullies appear. A network of gullies soon develop if the land is continued to be misused. These are known as ravines and irreparable damage may be caused if ravines are allowed to enlarge endlessly in a particular area.

Much as is the case with animal and human disease, gullies too may respond to various types of treatment and the disorder of the land controlled. However here it must be borne in mind that a permanent cure can be affected only if the root cause of the trouble is treated or in other words, the entire watershed or the area from which the water flows into the gully needs to be adequately treated.

In the humid regions, under normal conditions, the land is covered by a dense growth of trees, shrubs, herbs and climbers. This vegetative cover affords adequate protection to the soil against the agents of erosion. The force of the falling rain drops is broken and it gradually seeps into the soil. Thus, the infiltration into the soil helps to promote vegetative growth. This cycle continues for the benefit of both the land and the vegetation.

The trouble starts when this delicate balance is disturbed by the clearing of vegetation, overgazing or by disturbing the protective cover of vegetation in any manner. As the unprotected, fertile topsoil is quickly washed away by the surface run off, the water tends to concentrate more forcefully in the natural water courses and gullies result. Less and less water is able to soak into the soil to support the growth of vegetation. In the absence of roots to hold the topsoil together, it is quickly washed away by the surface runoff. Thus, a vicious cycle starts unless ways and means are devised and implemented to protect such lands.

Even as gullies develop, the topsoil continues to be washed away. Both the productive topsoil as well as the infertile subsoil of the lower horizons is deposited over the rich lands lying in the valley. Besides ruining valuable arable land and/or

pastures, forests lands; gullies may also encroach and at times disrupt highways, bridges and canals. This adds to the cost of their maintenance and affects travel. In the absence of roots, the process of soil formation is also seriously affected.

One of the commonest types of misuse of the land is the practice of cultivation of steep slopes without resorting to the accepted principles of terracing. Overgrazing and trampling of soil by cattle also aids in the formation of gullies. It has been seen that the steeper the slope the greater is the hazard of gully formation. Gullies tend to form when steep slopes are taken up for cultivation without adopting special measures to suit the extra ordinary conditions.

Very often the formation of a gully starts on the bank of a natural waterway (stream or river) which has been eroded to a severe magnitude. These quickly extend back into drainage area and increase in depth as they cut upwards along the slope. Branch or side gullies may be formed when these gullies cut across the natural drainage or depressions of waterfalls. Thus, a network of gullies or ravines soon develops.

CAUSES AND TYPES OF GULLIES

The main causes responsible for the formation of gullies are :

1. Removal of the protective cover of vegetation from the land.
2. Faulty cultivation practices.
3. Overgrazing and other forms of biotic pressure on the vegetative cover.
4. Construction of faulty water channels, roads, rail-lines, cattle trails, quarries etc.

Gullying may be of the following types :

RE-VEGETATION

Re-vegetation of the affected area is perhaps the most economical, effective and easy method to control the formation of gullies. Fencing helps in the establishment of vegetation in a gullied area. Re-vegetation may be brought about by natural or artificial means. Under natural re-vegetation the area is effectively fenced so that the natural vegetation gets a chance to re-establish itself. In artificial re-vegetation, sodding and planting is resorted for controlling a gully.

Under favourable conditions the local grasses of the area may be planted on the fringes of the gully. With time the grass growth gradually spreads to the different parts of the affected area. Kudzu (*Pueraria thunbergiana*) or tropical kudzu (*P. phaseoloides*) has been found to be fairly effective. Large areas of gullied land when covered by an adequate growth of grass may be adopted for the production of forage on a supplementary basis. In areas where the land is not too rough, kudzu may be cut to serve as a fodder for stall feeding. Hence, by its role as a high quality feed, kudzu plays the role of a double edged weapon. However, small gullied areas under kudzu can be ruined by grazing or even by a considerable degree of trampling.

If need be the run off may be diverted away from the gully head before control measures are initiated. For this purpose, either terraces or water diversion ditches may be excavated. Here it may once again be stressed that diversion of the runoff forms an important aspect of control of gullies and due attention must be given to it. The disposal of concentrated surface flow over unprotected or poorly protected tracts is likely to cause serious additional loss.

Terraces are constructed at the head of the gully for diverting the run off away from it. This helps in reducing the level of erosion within the gully. In areas where the slopes above a gully are too steep for terracing or if the catchment area is forested or under a cover of grass, diversion ditches are excavated so as to keep the run off away from the gully.

Revegetation measures are very successful under the following conditions :

- suitable soil and moisture conditions.
- the scouring action of the surface run off is prevented by diverting it.
- the gullied area is not allowed to be trampled under the hooves of cattle.
- adequate fire protection measures are taken up.

Once the pioneering plant communities have managed to improve the soil conditions, plants of the higher order establish themselves. This process takes a longer time in dry regions. However, success is attained fairly quickly under moister conditions.

Even though plants come up naturally in areas protected against the above listed factors, yet a number of influences hamper the final healing of the cancerous gully. These are :

(a) Continued soil erosion as a result of alternate thawing and freezing. This hazard is minimised by a mulch branches, straws or leaves which also help to catch and hold the plant seeds.

(b) Steep sides on the gully banks may also hamper the process of re-vegetation. It is difficult for unassisted plants to strike root under such conditions, until the sides cave in and a gentler slope is formed. Steep walls may be ploughed in or broken by a bulldozer or even dynamited in case it is economically feasible.

However, kudzu planted along the periphery of such gullies will tend to extend down into the gully and establish a fairly firm root system along the banks of even very steep sided gullies.

Despite adverse conditions, hardy plant species will come up easily in gullied areas if adequate protection is ensured and the runoff is diverted away from the gully. Weeds and dry zone plants are usually the first to appear. They have the way for other plants which follow after one or two seasons. After some years, the natural process is successfully able to gradually revegetate a gullied area with a succession similar to the natural succession of the area.

Artificial revegetation may have t o be resorted to in areas where the existing conditions do not favour the establishment of vegetation by natural means. As far as erosion is concerned, the results differ with the species and the type of method adopted to solve the problem. However, any succession, when well established is able to control soil erosion. Thus, the method of plantation becomes the main factor that determines the species to be raised in artificial revegetation.

Sodding is a commonly adopted method for raising vegetation by artificial methods in a severely gullied area. A good grass sod is able to carry more water of a higher velocity safely than under conditions where woody species are used to cover the slopes. A soddier water outlet can, at times be crossed, by heavy machinery in farming operations however, one with a woody climber cannot. Drainage ways with a good grass cover sometimes produce a good yield of fodder.

In sodding operations, sods are implanted in the soil in broad strips in the gully. They quickly grow and cover the entire gully. This is known as *strip sodding*. Another method of sodding is to implant the sods in patches all over the gully. This is known as *patch sodding*. In *random sodding* the sods are placed at random points all over the gully. The grass quickly grows and the entire gully is clothed with a thick layer of grass in a few months time. However, under dry conditions, it takes more time for the sods to establish in the gully.

MECHANICAL STRUCTURES OR CHECKDAMS

TEMPORARY CHECKDAMS : These are temporary structures erected across the flow of water in a gully. Check dams perform the following functions :

1. break the steep slope of the gully into a series of steps. This transforms the longitudinal slope into short drops with low risers and flat treads.

2. they help to break the force of the flowing water, thus reducing their erosive power.

3. the running water is forced to deposit its load at the checkdam as its velocity is greatly reduced. In larger check dams a small reservoir is created which allows the water enough time to shed its load.

4. the check dams increase the time of concentration of the water, by allowing it to percolate into the soil.

5. they collect enough soil and water for the eventual growth of a protective vegetative cover.

6. they check head or channel erosion till enough stabilising vegetation can come up at that critical point.

When temporary structures are used for gully control it is advisable to have a series of low structures rather than a large one. A series of temporary structures have the following advantages :

- low dams are less expensive to erect.
- they have less chances of failure than high dams.
- they can be better protected from overfalls by vegetative cover after these low dams have silted up and have completed their useful life span.

Temporary check dams are suited for gullies having a small catchment area. They should be extended far enough into the gully floor and into the sides of the gully so as to prevent them from being washed away and to reduce the possibility of

the run off seeping from under the check dam. A spillway of sufficient capacity may be provided for allowing the safe passage of water.

Permanent check dams : Permanent structures are used for controlling large gullies where temporary measures are either ineffective or inadequate. Such structures are required in gullies having a large catchment area and those which are to be retained as permanent waterways.

The velocity and quantity of discharge from a permanent dam is quite high and hence the slope below or between permanent structures should not be more than 10^{o} unless the channel bed contains sufficient rocks to prevent the gully bed from being scoured by the running water.

The stability of a permanent check dam constructed for controlling a gully is dependant on the stabilized grades in the channel below. A steep slope below the check dam will quickly wear away its base due to the scouring action of the overflow. This slope can be moderated either by changing the location of the structure or by providing a spillway apron at a lower elevation.

It is important to provide cut offs to check seepage and washouts from around or under the check dam.

CONTROL OF WIND EROSION

Wind erosion is a social and economic menace in many parts of India. If it is not adequately controlled it has an adverse affect on agriculture and other day to day activities. The primary factors which further aggravate the problem in various parts of India are :

- a prolonged spell of dryness
- absence of an adequate protective cover or vegetation

a broad, flat, slightly undulating terrain over which the wind can freely move.

Wind erosion causes the following adverse affects to agriculture and allied activities.

1. it renders the soil dry.
2. it tends to blow away the leaves and raw humus that otherwise would have added to the soil organic matter.
3. it causes excessive transpiration in plants.
4. strong winds also lead to premature fall of fruits in orchards.
5. movement of sand by wind tends to cover standing crops; block roads and even damage houses.
6. wind erosion destroys pasture lands.

Problem area

Wind erosion is a problem in the following parts of India:

(a) Coastal area

Tracts lying near the sea coast are lashed by high speed winds blowing in from the sea. These winds bring about the movement of sand and sand dunes occuring near the sea coast. The winds along the sea coast are salty and hence cause more damage to houses and other structures.

(b) Inland river sands

Inland sands usually lie along the plains of the major rivers such as the Ganga and Chambal. There is movement of

sand and sand dunes in the open areas lying along inland river sands.

(c) **Desert fringe and semi-arid areas**

These area consist of the tracts lying at the periphery of the Thar Desert, in part of Rajasthan, Haryana, Gujarat, Punjab and Madhya Pradesh. These are the areas in which the desert is said to be advancing.

(d) **Desert areas**

These is primarily the Thar desert lying in Rajasthan. Wind erosion is the most severe in this tract and there is movement of a colossal amount of sand and sand dunes. Moving sand dunes cover roads, bridges, railway lines and even human settlements.

(e) **Cold deserts**

These include the cold deserts of Ladakh, Lahaul and Spiti.

Major control measures

Wind erosion control measures are grouped into the following broad categories :

1. **Vegetative measures** : This perhaps is the most effective means of controlling erosion caused by wind. Vegetative measures include :

- raising wind breaks and shelterbelts comprised of trees, shrubs and herbs. These serve to break the force of the prevailing winds and protect the areas lying behind those belts from the action of wind.
- raising a suitable vegetal cover on moving sand dunes helps to stabilise them. Each shrub or herb

acts as a barrier against the force of the wind and forces it to deposit its load.

- other measures such as encouraging the growth of vegetation by adequate fencing also helps to control erosion caused by wind.

2. **Agronomic measures** : This includes a package of agronomic measures that may be adopted to control wind erosion on cultivated land. The main agronomic measures are:

- strip cropping by raising strips at right angle to the direction of the prevailing winds. Different food and forage crops are raised in these strips which break the force of the prevailing winds.
- two zone concept of tillage may be adopted to afford protection against wind. A narrow strip of soil is prepared to give good seed germination and inter-row areas are left blank so as to afford protection against wind erosion.
- tillage practices may be adjusted so as to create a rough cloddy surface or a furrow against the direction of the prevailing winds. This reduces the force of the wind near ground level and renders the soil fairly stable.
- the movement of the wind can also be retarded by leaving the stalks of the harvested crops in the field itself. This protects the soil from being eroded away when the the field is without a protective cover.

3. **Mechanical or structural measures** : These include the following measures :

putting up physical obstructions in the path of the wind so as to force it to deposit the material it is carrying. These may be wooden boards or even

dry stone walls which are put up at right angles to the direction of the prevailing winds.

moving sand dunes may be controlled by lining the windward and leeward slopes with loose rows of stones.

CHAPTER 12

PROTECTION AGAINST INSOLATION

Insolation pertains to the heat received from the sun. At times excessive insolation is harmful to plants including trees. It may lead to the drying up of seeds and young plants or the twigs and branches of trees. It may also scorch or crack the bark and wood of the trees.

Different forms of damage by excessive insolation have been discussed below:

DROUGHT

A long period without any rainfall is termed as a drought. The length of time in number of days may vary from region to region depending on the ecological conditions. Woody plants or their parts which have been dried by the sun have much the same appearance as if they have been killed by frost. Damage by drought first leads to the drying up of the flowers , leaves/needles and young shoots. They turn brown and shrivel up before finally falling off though dry leaves may remain hanging on the trees for a long time.

This is as a result of the prolonged spell of heat which abstracts much moisture from the plants and also from the soil. There is a great increase in transpiration through which plants pass off more water vapour than their roots can absorb from the soil. The soil base becomes drier and drier thus being unable to meet the demand of the plants. Thus the effect of drought is indirect as the suns' rays do not kill the plants directly.

Adverse effects:

The adverse effects of drought have been discussed in the following text:

1. **Species** : The adverse effect of drought varies from species to species. On basis of their tolerance to long spells of dry conditions species may be classed as drought hardy/tolerant or sensitive to drought. Common drought hardy species found in different parts of India are chir pine, khair, sisham, teak and semal.

2. **Age** : The damage done due to drought also varies with the age of the tree. Young plants are more susceptible to damage than old and mature ones. Sowings and plantings are more exposed to damage during the early years of their life until they have completely covered the ground. Thus saplings in the nursery are damaged easily by drought if they are not regularly watered.

In hot localities and on poor shallow soils without lateral shelter, plants upto an age of about 15 years may be seriously affected by drought, leading at times to their death. Older transplants on weedy ground suffer more from drought than younger transplants on fresh clearings as in the latter case rain and dew have more access to the soil.

3. **Locality conditions** : The danger from drought is more in the plains and low hills than in the mountains. The damage is severe on small flat hills and narrow ridges. So far as aspect is concerned, southern and south-western slopes suffer most from drought while on the north facing slopes the damage to plants by trees is the least.

Forests growing on calcareous soils particularly stony superficial soils above calcareous rocks suffer most from drought than those on stiff clays, sandy soils, sandy loams and loams.

4. **Soil covering** : A tall growth of grass and weeds covering the soil increases the damage caused by drought as their roots form a network in the soil thereby absorbing and transpiring the moisture which would otherwise have been available to the woody plants growing in or above the grass. On the other hand a light covering of isolated shrubs may prove beneficial by providing shade to the favoured species. Leaves

and moss and the humus resulting from their decomposition on the surface of the ground shelter the roots of the trees from the desiccating effects of the sun.

5. **Crop density** : Forests in which trees stand far apart suffer more damage from drought than well stocked forests. Isolated clean boled trees with smooth bark reflect the rays of the sun particularly at noon, thus drying up the soil around them. As a result natural regeneration may completely fail around such trees.

6. **Weather and season** : The drying up of young plants due to drought is recognisable early in the summer. If the dry weather continues for a longer time say upto July, more damage is likely to be done. Maximum plants die during this period.

Protection:

The following measures may be taken for affording protection against damage from drought:-

Regeneration:

1. Natural reproduction is preferable to artificial reproduction either by transplanting or sowing. In case the latter becomes absolutely necessary it is advisable to choose deep rooted strong transplants and cover the planting spots with sods or large stones. Nursery raised transplants when planted out in the forest, are able to withstand drought better than seedlings taken directly from the seed beds. In very dry years mound planting gives bad results. Saplings of coniferous species with balls of earth round their roots stand drought less than strong well rooted transplants.

2. During artificial regeneration the soil should be deeply trenched and sowing or transplanting of saplings should preferably be done with some

shelter at least for some time. Deep trenching enables the saplings to grow a firm root system. In years of acute drought and on poor dry soils moss may be placed between lines of sowing particularly in the hills where the same is readily available.

3. Both sowings and plantings should be done at the beginning of the rainy season preferably soon after the first few showers of the monsoon have arrived.

Nurseries:

1. The area of the nursery may be subdivided by narrow evergreen hedges to provide protection against the adverse effects of drought. Temporary side shade may be provided with the help of mats. A thatched roof covering may also be made use of.

2. The nursery beds may be trenched deeply in autumn and manured with compost, farm yard manure or burnt sods. This helps to keep the beds free from weeds and also aids in the development of strong and fibrous roots.

3. Nursery beds containing seedlings may be temporarily protected by sticking branches into the ground on the southern side of the beds or all round them or by covering them with mats supported by a temporary framework. The mats may be placed over the saplings only during the hottest part of the day. This may be withdrawn as soon as the rains set in.

4. Regular weeding is also a protection against drought as removing the weeds helps to prevent the soil from caking and renders it hygroscopic. Soft earth may be placed on either side of the

rows of plants after the beds have been weeded.

5. Watering is necessary during long periods of drought. The nursery beds may be watered or irrigated in the evenings and this must be done from time to time till the rains set in. However too much watering must be avoided as this leads to the development of superficial rootlets which tend to die once the beds become dry.

Tending:

1. All epicormic branches should be pruned from standards reserved in high forest or over coppice as they prevent the rain water and dew from being available to to young saplings and render the standards stag headed.

2. The standing crop should be kept as dense as possible and the natural soil covering preserved.

3. Trees along the boundary of a forest or along roads may be kept dense and the outer row allowed to branch down to the ground so as to exclude hot and dry winds from penetrating into the forest.

3. A series of horizontal trenches may be dug along dry slopes in order to retain the rain water.

Exploitation:

1. The seeding fellings on poor dry soils should be as less as possible though after a good crop of seedlings has sprung up the saplings may be rapidly or gradually exposed according to their demands on light so that they may get full benefit of rain and dew and develop rapidly.

2. Thereafter all isolated smooth barked mother trees be felled and the bare patches around their stumps planted up.

BARK SCORCHING

Bark scorching pertains to a common malady of trees which generally occurs on the sides facing the sun or exposed to hot and dry winds. It is first rendered visible by the drying up of the bark of the affected trees which assumes a reddish colour and then gradually splits length wise and horizontally from the stem and falls off in pieces. The injured sapwood turns brown with the colour fading gradually towards the sound or healthy wood.

The exposed wood is then attacked by spores of various species. By strong and repeated insolation the rot spreads in a wedge shaped manner down into the heart of the tree in the direction of the meduallary rays. The damage caused as a result is increased by the fact that a strong growth of grass and herbs tends to dry up the surface moisture of the soil.

Adverse affects:

Bark scorching is due to powerful insolation. If the sun beats directly on the stem of a tree its west and south west sides are considerably heated. The following adverse effects occur:-

a. The commercial value of the stem is decreased and bark scorching may even kill the young stems. Thus there is considerable loss of timber and increment which has a cumulative negative effect on the growing stock.

b. The adverse effects of bark scorching is different on different species. Those having thin and persistent smooth cortex free from cracks are more affected. Those species that produce a thick bark which is rough and fissured face less damage. Their dead and coarse bark is a bad

conductor of heat and it does not become heated to the extent that a smooth bark will be.

c. Bark scorching usually affects only the clear bole of a tree and generally its lower part from the base upwards. The damage is most severe to that portion of the stem which lies immediately above the root stock, where there is no underwood owing to the heat reflected from the ground. The taller the stem and the higher the crown above the ground the more exposed is a tree to scorching. Large knots or low branches localise the injury to that part of the stem which is below them. Stems covered with moss or lichens resist insolation as also the trees that are branched down to the ground.

d. Large trees tend to suffer more from scorching than smaller ones which due to the greater curvature of their stems radiate heat more freely than the former.

e. Bark scorching affects trees standing in the open only particularly those which have been recently exposed after remaining part of a dense forest. Trees forming a dense leaf canopy are usually not attacked as their bark cannot become heated like that of exposed trees though the latter do not suffer in the first year after excessive insolation sets in.

f. The locality where the tree or trees are growing and the nature of soil covering also have a bearing on the damage caused by bark scorching generated by excessive insolation.

Prevention and protection:

The following measures may be adopted for affording protection against damage by bark scorching:

1. Felling by which trees of susceptible species are exposed should normally be avoided.

2. While raising plantations a mixture of tree species should be adopted giving preference to ones having a dense foliage.

3. High pruning may normally be avoided in case of trees prone to be damaged by bark scorching.

4. The soil covering of humus in various stages of decay should normally not be disturbed.

HEAT CRACK

These are cracks developed in trees due to insolation, usually just at the onset of the summer season or in late spring when there is considerable variation in day and night temperatures. In the early morning hours the ground is still quite cold and when it becomes hot after sunrise the centre of the tree does not expand so much as the bark. This leads to the development of heat cracks which may extend for more than a few meters in height from the ground level.

As a result of the loosening and drying of the bark local decay may set in which affects the commercial value of the wood. However small heat cracks usually close up after some time without causing any permanent injury to the tree. The resulting injuries due to heat cracks are not very significant and thus no special protective or preventive measures need to be taken.

CHAPTER 13

PROTECTION AGAINST WINDS

Winds may be classified differently on various basis, by their speed, such as storms and gales or on the basis of their origin viz, land or sea breezes, the direction from which they blow viz southerly or westerly winds etc. There may be considerable damage to forests or trees from winds. Generally speaking the main forms of damage may be :

(a) Uprooting the trees or bending the stems or breaking parts of the tree.

(b) Drying up the soil

(c) Impeding height growth

(d) Hampering the formation of regular shaped crown of the trees

(e) Increasing the spread of insect pests by blowing them over a larger area.

PREVALANT WINDS

These are winds that tend to blow in a particular direction. Prevalent winds are the same for a region or locality. While hot dusty winds are the prevalent winds in the arid and semi-arid areas, the winds blowing in from the sea may be the prevalent winds in the coastal tract.

Adverse effects:

Prevalent winds may have the following adverse effects on trees, forests and the forest ecosystem as a whole:

(a) They may lead to the spread of the desert by blowing sand and other material in a particular direction. In fact sand-dunes too spread under the effect of prevailing winds.

(b) Prevailing winds dry up and disperse the soil and soil covering from slopes and ridges and laying them in depressions, hollows and other unwanted localities. The soil blown in this way could cover forest nurseries or recently raised plantations.

(c) They hinder the formation of dew.

(d) Prevailing winds help to spread the spores of fungi and the seeds of forest weeds.

(e) Hot and dusty winds dry up the soil and young plants and damage the foliage and fruits.

(f) Strong prevailing winds may lead to misshapen growth of the crown particularly near the sea coast and at high altitudes in the Himalaya where the trees may be stunted and bent in a particular direction due to the effect of such winds.

(g) Prevailing winds may also cause the breaking of tender shoots while damp winds near the sea coast also injure the trees by the salt they carry which the rain washes from their leaves into the soil rendering it salty and unfit for many kinds of vegetation. This influence may be seen for many kilometers inland away from the coast.

(h) Dry winds have more adverse effects on broadleaved trees than on coniferous ones.

(i) Seedlings and saplings particularly those raised from planting and sowing and also young coppice shoots suffer most severely from strong

prevailing winds until the ground is completely covered by their foliage and herbs. Coppice suffers more than high forest especially when the rotation is short

(j) The localities most prone to suffer damage from prevailing winds are-

- coastal and littoral tracts
- cultivated plains
- ridges and tops of mountains and hills
- unsheltered plateaux

(k) The amount of soil desiccation by prevailing winds varies with the nature of the soil and the condition of the winds. Fast winds lead to quick removal of moisture from the soil. The damper the soil the more water it looses though deep soils are dried less than shallow soils.

Soils covered with low vegetation loose more water than that covered dead leaves and humus.

(l) Under similar conditions, dry winds cause more damage than moist winds and warm winds more than cold winds.

(m) Prevailing winds also reduce the quantity of carbon dioxide in the air contained in the soil.

(n) Other adverse effects of prevailing winds are -

- dense growth of weeds
- failure of reproduction
- fall in increment

- forking in old trees
- spread of diseases
- depletion of the soil

Prevention and protection:

The following measures may be taken up for protection and prevention of forests and vegetative ecosystems from adverse effects of prevailing winds:

(1) **Windbreaks and Shelter belts** : Windbreaks are protective plantations raised for affording protection to areas in the leeward side against strong winds. They consist of a few rows of trees(with shrubs) suitably spaced so that the effect of the prevailing winds is minimised. Small earthen ridges may be formed and grasses likes *Saccharum* planted initially. Once the ridges have become stabilised tree planting is done. The spacing varies with the combination of species being raised.

Shelterbelts are a wide belt of trees, shrubs and grasses planted in rows usually at right angles to the direction of the prevailing winds. The main objects of raising shelterbelts are-

- to deflect air currents
- to reduce the velocity of the prevailing winds
- to provide general protection to the leeward areas against the effects of wind erosion.

- to protect the leeward areas from the desiccating effects of hot and dry winds.
- to prevent the deposition of wind borne material in the leeward areas.

Shelterbelts are planned in a way that they have a typical triangular outline. This can be done by raising tall trees in the centre. A certain degree of penetration by winds is planned as by raising an impenetrable shelterbelt the degree of protection decreases very fast on the leeward side. Under Indian conditions, shelterbelts having a width of about 50 mts are considered ideal.

In shelterbelts the ratio of height and width should roughly be 10:1. Its orientation depends on the direction and velocity of the prevailing winds. Shelterbelts may be raised in quadrangles if wind directions tend to change very often. Length is an important consideration for shelterbelts as at the fringes eddies tend to form. This leads to an increase in the damage done by winds.

In forests being worked regularly, strips across the direction of the prevailing winds should be left particularly where the clear felling system is being adopted.

Planting with a ball of earth is advisable in tracts affected by high speed prevailing winds. Sowings should run in a direction diagonal to that of the prevailing winds. It is preferable to raise a small shelterbelt of dense shrubs in advance of sowings.

(4) Conifers should be mixed with broadleaved species. Mixtures help to minimise damage by winds.

(5) All undergrowth that springs up across the direction of the prevailing winds affords protection against it and should be preserved till required.

STORMS

Storms include all winds caused by differences in atmospheric pressure resulting from unequal temperatures of the air in different localities. A current of wind sets in to restore the equilibrium of the atmosphere whenever it is thus disturbed.

A storm is a high velocity wind having a speed of atleast 20 to 25 mts per second. Its approach is accompanied by a barometric minimum. The velocity of a hurricane is atleast 35 meters per second. Cyclones and anti-cyclones are different types of storms classed on the basis of the direction in which they blow.

Adverse effects:

The adverse effects of storms have been discussed below :

(a) Storms tend to shake the trees very violently. They may give the trees a decided leaning in a particular direction or uproot it or break the stems and branches. The latter is known as windfall.

Whether a tree is bent, uprooted or its branches broken depends upon the following-

- on the intensity of the storm
- the resistance offered by the roots and/or the stem.

The stem tends to break when the resistance of the roots is more than that of the stem and uprooting occurs when the roots are weaker. There may also be considerable breakage due to one tree falling on top of the other.

The quantum of resistance varies from species to species and also depends on the soil conditions and the locality in which the tree is growing. Other variables which influence this are-

- length of the bole
- nature of the crown
- soundness of the wood
- density of the crop
- mode of formation
- degree or level of tending

(b) Storms not only overthrow single trees but also whole forests or their part. A forest may have narrow clearings cut into it by storms corresponding to their direction or large blanks may be made in the forest area.

(c) Breakage may be of the stem, fork, crown or branches. The stem may be broken off close to the ground or at some distance above it. Severe winds may entirely twist the entire crown off the trees or break the tops.

(d) Conifers are far more prone to damage by storms than broadleaved species. There may be

extensive destruction of coniferous forests though that of the latter is relatively rare.

(e) Storms mainly damage trees or forests of advanced age, the second or third half of a rotation being the most prone to damage. Extensive damage is rare in forests having an age of less than forty years and may occur only under exceptional conditions such as shallow rootedness of the young trees, soil without much consistency owing to saturation by rain, forests in exposed localities or when affected by storms of very high force.

The most common form of damage to young trees is by causing them to deviate from the vertical position and less in the form of uprooting and breaking of stems.

(f) The system of management being followed also has an effect on the damage done by storms. The high forests are the most exposed to danger from storms. The shelterwood compartment system in which mother trees are left standing evenly distributed over the felling also leaves the forest exposed to damage by storms. This system cannot be applied in localities prone to severe storms as the mother trees are quickly uprooted or broken.

Amongst the coppice systems that of lopping the side branches is the most prone to damage by storms as trees so treated have long narrow crowns on which the strong wind can exert pressure. There is less adverse effect on pollards and ordinary coppice the least amongst these systems. The coppice with standards system is also storm firm as only the standards can be damaged but they suffer less due to their

strong root development and uniformity of their crowns as they grow in the open.

(g) Long cylindrical stems with elevated and expanded crowns having high centres of gravity and affording leverage to the winds are prone to damage by storms. Thus standards in high forest are liable to be thrown or broken. Damaged or diseased trees such as forked trees, those with decayed roots, or injured by animals , affected by insect pests and pathogens are extremely prone to wind break which may occur at the damaged or diseased portion.

(h) Other parameters affecting the damage done by storms are listed below-

- locality in which the tree or forest is growing
- configuration of the ground
- nature of the soil
- weather conditions accompanying or just preceding the storm.
- season or part of the year in which the storm is occurring.
- density of the forest

(i) Besides the above the direct and indirect damages caused by storms are given below-

- loss of increment
- breakage of the timber as a result of which it may become fit only for use as firewood.

- damage to young growth and breaking of the underwood as the tall trees fall over due to severe storms.

- increase in the efforts required to exploit and regenerate the forest affected by storms.

- irregularity in age classes as trees tend to be haphazardly damaged by storms..

- invasion of weeds in the blanks and regeneration areas where the trees have been blown down by storms.

- increase in the attack of bark beetle

PREVENTION AND PROTECTION

The following measures may be adopted for preventing and protecting trees and forests against damage by storms:

Regeneration:

(1) Wherever possible, broadleaved trees should be favoured. In the hills the conversion of broadleaved forests to pure conifers should be avoided.

(2) Extremely damp localities must be drained before regeneration fellings are commenced.

(3) The growth of sturdy, storm firm trees may be ensured by using tall and strong transplants upto 3 mts. high.

(4) Deep rooted trees may be mixed with shallow rooted ones.

(5) Protective belts around boundaries of forests and farmlands may be maintained where it is feared that severe storms may cause extensive damage. Boundary ditches may not be dug in such cases as they may cut the roots of the trees.

Tending:

(1) Early, frequent and moderate thinnings should be made in order to ensure the development of normal root systems, sturdy stems and regular shaped crowns. During thinning operations, as far as possible without interfering with the proper density of the crop, all trees that have suffered injury to their bark, or those that are forked, diseased or affected with fungi.

(2) All trees along the boundary of a forest prone to damage by storms may be allowed to branch low down the stem.

(3) Endangered tress along the boundary of forests standing over young growth may be temporarily preserved by thinning out their crowns and cutting those branches which extend at right angles to the direction of the prevailing winds.

Forest working:

(1) Long rotations may be avoided as the forest area exposed to danger from storms increases in proportion to the length of the rotation.

(2) Mountain forests exposed to storms should be regenerated with the help of the selection system. Priority must be given to the regeneration of the mountain top with the slopes being worked only when this has taken place.

(3) Regeneration in narrow strips commencing in the direction opposite to that of the prevailing winds should be substituted for regeneration extending simultaneously over the entire compartment.

(4) Forests should normally be regenerated in the direction opposite to that of the prevailing winds so as to contain a constantly graduated succession of young forests on the windy side of the older forests. This is a good protection against storms and other very strong winds.

However this type of succession of felling areas is likely to encourage insect attacks and is not very efficient. Thus the age-classes may be manipulated into a number of cutting series running more or less parallel to one another.

(5) Felling areas should have long straight boundaries as fellings in outlying corners of a forest may easily lead to damage by storms.

(6) In areas prone to storms standards of shallow rooted species become useless.

(7) In areas where there is a danger of storms, stumps should not be dug up in preparatory and seeding fellings. After storms have damaged valuable middle-aged forests further damage may be prevented by thinning out the crowns of trees left standing on the exposed sides of forests.

Treating windfalls and wood-breakages:

The following line of treatment may be followed in case of windfalls and wood-breakages from storms:

(1) The broken or damaged material should be converted as soon as possible with both manual and mechanical means. This should be removed from the forest stripping the bark from all stems and broken pieces. Trees that are still standing obliquely or rest against other trees can be left till the following working season.

(2) All wood that is not fit for being used as timber may be split and stacked up in a well created manner for use as fuel. All other waste material may be converted into charcoal or given to the local population for use as fuel.

(3) Stems that cannot be sold or used at once should be barked to prevent insect attack.

(4) Stumps and roots of coniferous trees damaged by storms should be grubbed out and split up even if some loss of timber is involved in this process.

(5) In case due to some reasons it is not possible to deal with all fallen trees and broken wood immediately after a storm the trees uprooted with balls of earth may be left for a year.

Treating forests damaged by storms:

The following measures may be adopted for treating forests damaged or severely affected by storms. The line of action will depend on the prevailing conditions such as-

- locality conditions
- species in the forest
- prevailing climatic conditions
- objects of management

local demand for small wood and fuel which may be quite high in many parts of India.

severity of the injury

(1) All mature or nearly mature forests that have been severely injured by storms should be felled or worked earlier than otherwise planned, particularly those forests which have become blanks. However if the storm has created only a few blanks the fellings need not be preponed.

(2) Small blanks formed due to falling of single trees or small groups of trees need not be planted as plantations will be unsuccessful in such areas. In any case the crowns of the larger trees will close the gap created by the storms in the next 10 to 15 years. However larger blanks have to be planted up before they become covered with weeds unless natural regeneration can be readily established in a short time.

While planting blanks, about 8 to 10 mts should be left unplanted as plants within this strip tend to suffer from the shade of the surrounding tall trees.

(3) It is difficult to decide upon a line of action in the case of pole-wood which has been broken by storms. Premature fellings should be done only under the following conditions-

- when the damage is very severe and extensive both in terms of areas and volume of timber.
- when the damaged forests interfere with the planned or normal cutting series.

when the removal of these poles is not likely to expose the neighbouring forests to storms.

(4) In most cases the felling of broken poles will be considered in connection with the volume of broken timber from the older aged compartments.

(5) Generally speaking the treatment of damaged pole-woods will vary as per the variables listed below-

- the species of trees in the forest
- the locality conditions
- the area of the blanks formed as a result of damage by the storm.

(6) Small blanks in a pole crop need not necessarily be planted for the same reason as the older aged crops. The surrounding crop is likely to fill up these blanks in a short time. Thus planting them becomes unnecessary. However larger blanks in the pole crop have to be tackled immediately.

(7) Forests consisting of damaged pole crop in which natural regeneration is intended may be trained up by means of heavy thinnings so as to produce seeds earlier than usual.

(8) Usually little damage is done by storms to thickets of saplings or to coppice shoots.

CHAPTER 14

PROTECTION AGAINST HEAVY RAINS AND HAIL

Heavy rains and hail are the cause of damage to trees , forests and the wild animals living in them. This chapter discusses the adverse effects of heavy rains and hail.

I. HEAVY RAINS

Heavy and prolonged rainfall and the resultant torrents/floods cause severe damage to the forest and the ecosystem as a whole. The damage caused by heavy rains and the protective/preventive measures have been discussed in the following text.

The main forms of damages are -

- rain waters carry away the dead leaves, raw humus, seeds and also the soil.
- they uproot the young plants the roots of which are not sufficiently developed such as seedlings and recently planted transplants brought from the nursery.
- by causing local swamps, destroying roads and ditches.
- by loosening the roots of trees.
- by preventing fruits from ripening and breaking them off.
- by destroying or damaging the habitat of wild animals including nests of birds.

Adverse effects:

There are many adverse effects of rains on forests. This depends on the following:

(i) The force and volume of the rainfall, its frequency and intensity.

(ii) The age of the forest trees

(iii) The locality factors

The damages outlined in the above text are the main adverse effects. Under special conditions these may be-

(1) Only young plants whose roots are not fully developed may be prone to be uprooted during heavy rains. They are primarily young germinating seedlings and transplants brought from the nursery and planted in the fields.

(2) Steep slopes with loose light soils which are neither covered with woody growth nor with herbs, moss or dead leaves are the most prone to damage. Loose soil on saturation with rain renders the roots of the trees less secure against windfall.

(3) Clayey soils are also injuriously affected by heavy rains as a crust forms on their surface excluding air from the roots of the plants.

Measures for prevention and protection:

The following measures for prevention and protection of damage against heavy rains may be adopted:

(1) The forest growth and natural covering of herbs, moss and dead leaves may be maintained on all steep slopes exposed to denudation. In high

forests it is advisable to go in for natural regeneration under the shelterwood system. However on slopes coppice system is less heavy than high forest and it also affords protection to the soil.

While regenerating such localities artificial measures may be adopted. The slopes may be terraced to prevent damage by heavy rains and planting is preferable to sowing. This may be done in horizontal lines commencing at the top of the slope.

(2) On dry slopes a system of horizontal leaf catching or protective trenches may be developed. These trenches vary in width and tend to retain the excess water after the rains.

(3) The following activities must not be carried out on steep slopes in order to afford protection against heavy rains-

- extraction of stumps
- grazing by all domestic animals
- trenching the soil
- removal of leaf litter

(4) Ditches and culverts should be formed on forest roads and kept free from weeds , dead leaves and silt in order to afford protection against the effects of violent rainfall.

(5) Standard soil and water conservation measures may be adopted in all forest areas and plantations to protect against the ill effects of heavy rains. These include the formation of check dams and gully plugging etc:

II. HAIL

Hail is another climatic phenomenon which has severe adverse effects on trees and forests. This is more pronounced in areas prone to hailstorms.

Adverse effects:

The adverse effects of hail have been discussed in the following text. The amount of damage done depends on the size of the hailstones, the intensity or force of the hail storm and the overall age of the forest.

(1) Hail completely beats down young plants and injures saplings, poles and young trees by breaking off leaves, flowers, fruits, young twigs and leading shoots and by stripping off flakes of the bark either in small patches or short strips thereby exposing the cambium.

(2) The marks of the wounds made by hail in the bark of trees are often noticeable for a considerable time.

(3) Birds and small animals such as hares may be injured or even killed by hail storms. Their nests are also destroyed.

(4) Wounds made by hailstones leave the trees open to attack by insects and fungi.

(5) Young plants having an age of upto 15 years are the most prone to damage by hail. One to two year old plants are readily destroyed by hailstorms. Sowings particularly when on a large scale suffer more than plantations. Poles suffer less damage than younger plants while severe damage is rarely done to trees having an age of more than 30 years.

(6) Other adverse effects of hail are -

- loss of increment
- incidence of disease and insect attack
- deformed growth
- decrease in the production of seed
- loss in the commercial value of the timber.

Protective measures:

The following protective measures may be adopted against adverse effects of hail :

(1) Forests in localities prone to hailstorms should be worked under the selection system.

(2) Tops of hills and ridges must be kept under a dense cover of vegetation.

(3) Strong transplants should be used for filling all blanks in forests

(4) Broadleaved trees must be mixed with coniferous species.

(5) Severely damaged saplings and poles must be removed from the forest as soon as possible.

CHAPTER 15

PROTECTION AGAINST SNOW

Snow is another climatic phenomenon which has an adverse effect on trees and forests. In India forests occurring in localities receiving snowfall are restricted to elevations of over 2000 mts in the Himalayas. These include the temperate, sub-alpine and alpine forests.

Injuries to forest plants is caused by the downward pressure of the snow when lying on their branches. The resulting damage occurs either as snow pressure or snow break.

a) **Snow pressure**: The action of snow pressure consists in the bending or uprooting of entire stems, often with a ball of earth around their roots or branches may be torn out of the stems.

b) **Snow break**: This occurs when the stem or branches yield to the weight of the accumulated snow on them and break across the bole, or the crown or branches. Bending occurs when the ground is soft and when it is frozen there is breakage.

Snow sliding down the hill may cause a special form of injury , crushing or bending the vegetation which lies in its path.

Adverse effects:

Both direct and indirect adverse effects of snowfall have an impact on trees and forests. The direct results of excessive snowfall resemble those by storms. The indirect damage include-

- softening of the soil and rendering it prone to erosion and landslides.
- increase in the discharge of mountain streams and rivers which causes floods and erosion.

The adverse effects of snowfall vary under different conditions as discussed below:

1. **Species**:

The quantum of damage depends on the species of trees forming the forest. Trees with pendulous or flexible leaders or branches like deodar are adapted to grow in regions where snow occurs regularly in each winter. On the other hand species having brittle attachment of the branches to the stem may withstand frost but are broken to pieces by the weight of snow.

The lower part of the stems of trees growing on mountain slopes exposed to heavy snowfall curves outwards before becoming vertical due to the pressure of the snow which accumulates behind it when it is young. In hollow depressions on steep slopes the weight of the accumulated snow is so much that it tends to slide down in masses and crush the seedlings that fall in its path.

2. **Part of the tree:**

Young trees may be bent down by the effect of snow individually or in masses with or without a ball of earth around their roots. A less common form of damage is the tearing out of branches by wet snow from the stem due to which it becomes useless as commercial timber and more liable to fresh breakage. In case all the branches are torn out in this manner the leading shoot dies. This form of injury is common in the case of pines

The tender and young branches are more prone to damage by snow particularly in the case of saplings and poles.

3. **System of management:**

Forests being managed under high forest systems are more prone to damage from snow break. Forests in which trees of each compartment are of even age and height are more prone to damage by snow than unevenaged forests such as those

managed under the selection system. In even aged crops snow may lie in masses like a flat roof over the crowns of the trees particularly when the forest is densely stocked whereas in uneven-aged forests the snow has a greater surface to cover as the tree tops are irregular and it reaches the ground by falling between the crowns of the trees. In the latter case winds also enter the forest more freely and are able to shake off the accumulated snow from the crowns of the trees.

Thus in localities prone to very heavy snowfall, the selection and group systems are more suitable than any other system. In the coppice with standards system, the tall standards tend to suffer damage by snow soon after other trees have been felled or removed.

4. **Age:**

The age of the crop too is a variable in the quantum of damage by snow. Thickets upto an age of about 20 years do not suffer much damage as a result of their elasticity while forests over 60 years in age suffer less damage due to their greater size. The level of damage is most between 20 to 60 years of age.

5. **Locality:**

Forests occurring high up in the hills are more prone to damage by snow than their counterparts in the valleys where the snow melts quickly.

6. **Thinnings**:

Forests that have been regularly thinned are usually less liable to damage than unthinned woods due to-

- better development of their crowns
- more snow reaches the ground in thinned forests

- in thinned forests the weight of the snow which rests on the crowns of the trees is less than that in the case of very dense and untended forests

- the wind is also more effective in shaking off the snow from the trees in thinned forests.

7. **Weather conditions:**

The effect of snow is more damaging in wetter and turbulent conditions. Small flakes pass more easily between the branches of the trees and dry snow is more readily shaken off from the trees than damp and wet snow. There is more breakage in frosty conditions when the wood is brittle.

Considerable damage is done when a thaw sets in after a snowfall and is followed by frosty conditions, another snowfall and a strong wind. This combination of weather conditions tends to cause extensive damage to forests.

Prevention and Protection:

The following measures may be adopted for prevention and protection against damage by excessive snowfall:

(1) Species that are highly prone to damage by snow should not be planted in snow bound localities that too as a pure crop.

(2) The natural mixture of species should be maintained in the case of natural forests. Such forests should as far as possible be regenerated by natural means.

(3) The clear felling system must not be adopted in localities where there is considerable damage due to snow. Even otherwise this system is now not adopted in the Himalayan region

(4) Sowings in the open are to be avoided. If planting is carried out then strong and sturdy saplings raised for 2 or 3 years in the nursery may be planted so as to enable them to grow into strong and snow resistant plants.

(5) The excess growth of grass and weeds should be removed as they are likely to be pressed down by the snow over the saplings of the favoured species thereby killing them.

(6) Timely thinnings are an important preventive measure against damage by snow. These must be done in accordance with the accepted principles of silviculture and as per the broad objects of management.

(7) All injuries to the bark of trees must be avoided. Even resin tapping in localities prone to damage by snow must not be done.

(8) In forest nurseries of high elevations, the snow must not be allowed to accumulate on the beds. It should be shaken off the saplings soon after snowfall.

(9) The selection system should be adopted in mountainous regions as this produces uneven heights in the crown. Uniform covering of the crop with snow is thus prevented.

(10) The treatment of snow damaged forests depends on their age and the species of which they are composed and also the kind of damage that has been done.

In case of extensive damage all bent and broken stems should be removed from the forest. Those which have been partially injured need not be removed if they have an even chance of

recovery. Stems that have bent over the ground may recover their erect position due to inherent elasticity and their tendancy to strive towards light. More over their retention helps to keep the soil covered.

Young coniferous forests which have been broken in patches and strips may have to be planted up on a large scale. Older forests suffering similar damage may be underplanted with the same species or a mixture of snow resistant species.

11. It is essential to carry out immediate assessment of the damage after heavy and excessive snowfall. A register may have to be maintained at the range level to keep track of all such adverse effects and injuries.

CHAPTER 16

PROTECTION AGAINST FROST

Frost usually occurs due to lowering of the temperature of the air in contact with the earths' surface to below the freezing point. Many parts of India experience frost during the winter season particularly in the months of January and February. Early frost may occur in mid-December while late frosts are experienced in the middle of March.

On basis of the mode of occurrence and origin, frost may be classed into the following :

(a) **Radiation frost** : This form of frost is produced by excessive loss of heat by radiation during clear skied winter nights when the air near the ground level tends to cool down very rapidly by radiation. This is more prominent when the atmosphere is dry and calm. The temperature quickly falls below the freezing point. Ice crystals are then formed on the ground and on objects near the surface. This condition is known as ground frost. Radiation frost usually occurs in open areas and leads to the dying back of young plants.

(b) **Pool frost** : This form of frost occurs as a result of the accumulation of a considerable depth of cold air flowing down into natural depressions from the adjoining regions. It has a more harmful effect on the vegetation as the chilling effect is likely to extend upto a considerable effect.

Pool frost is a typical feature of mountainous areas where the air near the mountain slopes is cooled. As it begins to become heavy the cool

air moves down into the valley areas with its place being taken by fresh light air which in turn too becomes chilled and moves into the valley bottom or depression. A typical example of pool or convection occurs in the Dehradun valley where the cool mountain air descends both from the lower Himalayan and siwalik slopes. On certain nights the pool of frost may be more than a hundred meters deep.

(c) **Advective frost** : This form of frost occurs as a result of cold air brought in from elsewhere. It tends to occur in open areas like the Ganga plain which are swept by cold waves during winter nights. In the winter season a deep western depression entering India from the north-west is usually responsible for the extremely cold conditions experienced in the north Indian plains. This cold wave is harmful for plants and animals.

A frost pocket or frost hole is a local area which experiences more frost than the surrounding area or locality.

Adverse effects of frost:

Frost has many adverse effects on trees, vegetation and the ecosystem as a whole. These have been outlined in the following text

(1) **Death of young plants** : The soil moisture tends to be frozen by even light frost and in the morning when the young plants growing in these localities are exposed to direct sunlight they tend to perish due to increased transpiration at a time when their roots are unable to draw up water from the frozen soil moisture. This causes the death of hundreds of sal saplings each year in the plains of Uttar Pradesh during the winter months.

Frost heaving is a related phenomenon which causes the death of young plants. During frosty nights the soil moisture

is frozen leading to the formation of ice. As the volume of ice is more than the water it replaces, the soil is heaved or lifted up. This also affects the plants growing on the soil which tend to be lifted up from their original position, thereby dislodging the roots from the soil and resulting in their death.

(2) **Cell damage** : Very often in frosty nights the moisture present in the intercellular spaces of the plant gets frozen into ice. In this process water from the adjoining cells is also withdrawn, causing their dehydration and ultimately leading to their death. If the frost conditions are very severe, the moisture present in the cells may also freeze into ice. Upon freezing the water expands and disrupts the contents of the cell by mechanical stress. Formation of ice is by both the above inter- and intra-cellular ways. As a matter of fact the former is more harmful than the latter.

3. **Injury to the crowns of trees** : Heavy and prolonged conditions of frost are likely to kill the crowns of saplings and poles. This may occur in areas where frost is fairly thick.

4. **Frost cracks** : At times when due to frost the moisture present in the wood is frozen into ice and water is drawn from the adjoining cells. This leads to the formation of cracks in the wood as the outer layer shrinks and dry up more rapidly than the warmer inner layers. The frost cracks are usually longitudinal and they appear along the stem or bole of the tree which may be covered by callous growth with time.

Frequent opening and closing of frost cracks may lead to the formation of pronounced ridge like features on the stem. These are termed as frost ribs.

5. **Canker formation** : Under conditions of heavy frost, a branch may die off upto the stem leading to callus formation. Subsequent frost may kill the callus being formed at the base of the branch. This is repeated year after year and the affected area spreads like a cancer. The diseased area is highly prone to be attacked by fungi.

FROST RESISTANCE

Frost resistance refers to the ability of a species to withstand conditions of frost. The following parameters have a bearing on the resistance or power of a species to withstand frost:

(a) **Size of the cell** - plants having small sized cells are more frost hardy or resistant

(b) **Water content** - the more the water content in the cell the greater is the danger of ice formation.

(c) **Osmotic factor**- the resistance to frost has a direct relationship with the osmotic concentration of the cells as the freezing point of the cell sap becomes lower.

(d) **Permeability to water** - the higher the permeability of the protoplasm to water the more is the resistance to frost.

(e) **Water binding colloids** - there is an increase in the resistance to frost with increase in the level of water binding colloids in the cells as they bring down the amount of water likely to be frozen both within and outside the cell.

(f) **Temperature conditions** - a sharp decline in temperature is liable to cause more harm than a gradual decrease as a sharp fall increases the formation of internal ice. Prolonged freezing leads to damage in even frost resistant species.

(g) **Seasons** - there is a variation in the resistance of trees to frost with seasons. Species that are able to withstand winter frost may be injured by frost in the spring season.

(h) **Light conditions** - the more the duration of light the lesser is the resistance to frost as in such cases there is a larger photo period. Due to less light the reserve carbohydrates are likely to be converted into sugar thereby increasing resistance to frost.

(i) **Minerals** - minerals like nitrogen stimulate growth thereby reducing the resistance of trees to frost.

Frost hardiness:

Frost resistance is the capability of various species to withstand frost. Based on this tree species may be classed as under-

(a) **Frost hardy species** : These species are able to withstand conditions of severe cold. Some examples are - *Acacia catechu, Anogeissus pendula, Dalbergia sissoo, Diospyros melanoxylon, Hardwickia binata, Madhuca indica, Madhuca latifolia, Ougenia oojeinensis, Pinus roxburghii, Stereospermum* sp, *Toona cilliata, Zizyphus jujuba* and *Zizyphus mauratiana.*

(b) **Moderately frost hardy species** : Such species are not affected by conditions of mild frost but may be injured by severe frost particularly in their youth stage. Some examples are- *Adina cordifolia, Anogeisus latifolia, Bombax ceiba, Cedrus deodara, Dalbergia latifolia, Gmelina arborea, Morus alba, Pongamia pinnata* and *Pinus wallichiana.*

(c) **Frost tender species** : These species are highly prone to damage by frost. They include *Acacia arabica, Azadirachta indica, Boswellia*

serrata, Garuga pinnata, Shorea robusta, Tectona grandis and *Terminalia* sp.

Preventive and Protective measures:

The following measures may be taken for preventing damage from frost and taking protective measures. These may be adopted when the forest is being regenerated, managed, tended and exploited/utilised.

(1) All wet localities and swamps must be drained before a forest is restocked. Moisture is not always favourable to frost. It is understood that dry humus has a low specific heat and is a bad conductor while wet humus has a high specific heat and is a good conductor.

(2) Frost tender species must not be grown in the open. In any case when such species are to be planted they must be preceded by nurse trees of hardy species.

(3) In natural forests where stocking is to be done by natural means, the shelterwood system is to be adopted. Pruning of low branching shelter trees may be done for promoting air circulation.

(4) In case of plantings, strong and hardy transplants with balls of earth may be used with mound planting being preferable to other methods. This helps the plants to survive under conditions of forest. In wet localities ridge planting may be adopted.

(5) In some areas protective belts may be formed of frost hardy species.

(6) Where large areas to be restocked are covered with a dense growth of grass or other herbs, they

should be cleared before taking up sowing or planting.

(7) In forest nurseries where there is danger of damage by frost the following precautions may be taken-

- they should be situated on northerly or north-westerly aspects.
- seed sowing should not take place too early and the seed beds may be adequately covered.
- in conditions of extreme frost, smoky fires may be kindled during the night to prevent damage.
- the nursery beds may be shaded if necessary.

(8) In order to promote the interchange of air in the lower strata of the atmosphere all stems may be pruned off their lower branches that stand over young growth.

(9) The natural covering of the soil consisting of dead leaves, needles and moss should be preserved as a protection against damage by frost.

(10) All parts of plants which inspite of all these precautions have been killed by frost should be immediately pruned and those plants that are frozen must be cut at ground level.

CHAPTER 17

GRAZING AND BROWSING

India has the largest cattle and buffalo population. About one sixth of the cattle population of the world and nearly half of the total buffalo population lives in India. This population has been going up in the past few decades and combined with the ever increasing human population it is causing tremendous pressure on the forest.

The main types of livestock found in India are - cattle, buffaloes, sheep, goats, camels, equines, pigs and poultry. Ironically the population of all these types of livestock has increased haphazardly. The accompanying tables shows the increase in the population of various types of livestock from 1951 to 1988.

Livestock Population in India

(in million)

Livestock	1951	1951	1971	1981	1985	1988
Cattle	155.2	178.8	179.4	181.0	179.99	192
Buffaloes	57.1	57.9	60.2	63.8	63.72	69
Sheep	38.9	40.3	42.4	44.9	46.7	48
Goats	47.0	68.5	70.3	74.7	78.5	96
Camels	NA	NA	NA	NA	0.1	NA
Equines	0.4	0.9	1.1	1.4	1.8	02
Pigs	3.4	6.4	NA	NA	NA	10
Poultry	110.4	136.7	143.5	165.9	189.4	193

Livestock plays a pivotal role in the national life. In many ways the cultural life of rural India is intimately connected with these animals. This is particularly true in case of cattle which are the main source of power in ploughing operations and rural transport. Livestock also provide essential products of animal

origin such as milk, eggs, meat, wool etc. They also provide valuable organic manure and very often animal dung is used for heating the hearth in rural areas. For years to come, livestock will continue to serve as the mainstay of our rural economy particularly in the field of agricultural operations and transport.

However, an analysis of the increase and distribution of the livestock population shows that the fodder requirement is being met mainly from about 3.5% to 4.0% of the total geographical area. It has been estimated that over 750 million tons of green fodder is needed each year and for this the land area available is :

Total geographical area - 238 million hectares.

Area under permanent pastures - 12.4 million hect.

Forest area partially available - 75 million hect.

In India there are about one-sixth of the world population of sheep and goat. There are no reliable estimates regarding their contributions to the national economy but this may be about Rs. 200 to 225 crores per year based on the production figures for wool, mutton, skins etc. Sheep and goat rearing forms the main occupation of the people in the following tracts :

- in the high altitude areas of the Himalayas.
- in other remote hilly tracts.
- in drought prone and desert areas.

The National Commission on Agriculture has identified the following four sheep and goat rearing regions in India :

i. The northern temperate region comprising of Jammu and Kashmir, Himachal Pradesh and the hilly parts of Uttar Pradesh.

ii. The northwestern region comprising of Punjab, Haryana, plains of Uttar Pradesh, Rajasthan, Gujarat and Madhya Pradesh.

iii. The eastern region comprising of Bihar, Orissa, West Bengal and the north-eastern States.

iv. Southern region.

The population of sheep and goats is going up steadily. They cause severe damage to the land and hence their population needs to be controlled. The National Commission on Agriculture (1976) wrote about the need to reduce the numbers of goats in India, in the following words, ".... This can produce a devastating effect on vegetation due to browsing habits of goats. The sheep and goat owners should, therefore be educated on the advisability of reducing the number of goats and improving their .... Further restrictions on grazing of goats on specially developed grasslands should be imposed. At the present rate of growth the number of goats is likely to be of the order of 70, 74, 78 and 90 million in 1975, 1980, 1985 and 2000 respectively. It may not be possible to arrest their number in the normal course upto 1980. But we definitely feel that the slaughter of goats for meat purposes should be increased so that the rate of growth of population of goats may come down to a level of 67 million by 1985 and get stabilized at about 40 million by 2000 A.D. We expect that by then the quality of sheep would get considerably improved, yielding higher quantity and better wool and mutton."

GRAZING AND BROWSING PATTERNS

The following are the main grazing patterns found in India :

(a) **Migratory grazing** : The livestock migrates from one place to the other in search of fresh pasture. Migration may take the cattle to areas of lower altitude in winter and to high level grazing grounds in summer.

(b) **Twenty four hour grazing** : The livestock remain in the forest or rangeland for all twenty four hours.

(c) **Day grazing** : The livestock are driven to the grazing grounds during day time for 7 to 8 hours.

(d) **Penning and stall feeding** : The livestock are fed on or from rangelands or feed is collected from forest areas and fed to the cattle. At times penning and stall feeding is adopted in a combination with grazing. This reduces the damage to the land.

GRAZING REGIONS OF INDIA

India can be divided into the following grazing regions :

i. **Western Himalayan region** - comprising of Jammu and Kashmir, Himachal Pradesh and Uttar Pradesh hills.

ii. **Eastern Himalayan region** - comprising of Darjeeling hills, Sikkim and Arunachal Pradesh.

iii. **Western region** - comprising of Rajasthan, Gujarat and arid tracts of U.P., Haryana and Madhya Pradesh.

iv. **Indo-Ganga Plain region** - comprising mainly of the tracts forming part of the Indo-Ganga Plain.

v. **North eastern region** - comprising of the north-eastern states.

vi. **Central region** - comprising of the central Indian tract of Madhya Pradesh, Maharashtra, Orissa and Bihar.

vii. **Southern region** - comprising of the four states of south India viz. Karnataka, Andhra Pradesh, Kerala and Tamil Nadu.

DAMAGE CAUSED TO THE FOREST BY DOMESTIC ANIMALS

Under this heading, damage caused to the forest both by grazing and browsing domestic animals has been discussed.

i. Animals graze the seedlings of the desired species alongwith grass, herbs etc. Thus, the problem of regeneration is created, which affects the composition of the future crop.

ii. Seedlings of the desired species are crushed and trampled under the hooves of cattle. In some cases, the roots of such seedlings may be exposed by trampling. In both cases, death of the seedlings takes place.

iii. Indiscriminate and heavy grazing causes problems for the soil :

(a) the soil is made compact;

(b) there is reduction in porosity;

(c) soil aeration is affected;

(d) hooves break down soil aggregates which give a crumby structure to the soil;

(e) due to the effect of hooves on the soil, there is a decrease in the water absorption capacity;

(f) the soil becomes highly susceptible to accelerated erosion and other associated problems, and

(g) there is an increase in the surface run off.

iv. When hooves of cattle make the clayey soil compact, there is a considerable change in water absorption capacity increasing the run off.

GRAZING MANAGEMENT

Maximum production from a particular grassland or forest is dependant on scientific management and utilization of the available resources. The following are of primary importance :

(a) securing a balance between the number of animals and fodder resources.

(b) grazing during the correct season.

(c) ensuring a scientific distribution of livestock over various parts of the grassland or forest.

OPTIMUM LIVESTOCK NUMBERS

Maintaining the number of livestock on a grassland or forest at an optimum level is necessary for the following reasons :

- it keeps the grassland at an optimum level of fodder production
- it ensures the well being of the livestock.
- it renders the enterprise economically feasible.

However, levels of range forage can neither be weighed nor measured. Very often heavy grazing leaves behind a residue that must feed the livestock in times of drought or economic emergency. Livestock are able to survive on this residue for a fairly long time.

Overgrazing causes severe damage to the grassland. However, most grassland owners do not realise the gravity of the problem even though they do know that prolonged grazing is harmful.

Impact on forest production : Optimum levels of livestock numbers has a direct bearing on the well being of a forest. By maintaining an optimum livestock population on a particular forest, the resistance of the animals to diseases also increases. They are able to withstand adverse conditions and their average life span is increased.

Economically speaking, overgrazing reduces the production of fodder. Short term economic benefits can be derived from overgrazing but the ability of the land to recuperate plays an important part in the nature of damage that is likely to be caused.

GRAZING AND PLANT SUCCESSION

Soil, climate and vegetation have an important bearing on the response of a particular area to grazing. Under a specific set of climatic and edaphic factors, a particular combination of vegetal community develops; grows fairly well and regenerates itself.

In nature, climax grass vegetation is to be found either in areas that are undisturbed by man or in tracts that have been under scientific management for the past many years. Overused grasslands that are under various forms of grazing are not a climax stage in the development of succession. The degree of deterioration depends upon :

- the causes of deterioration
- the period of misuse/overuse
- other biotic factors.

The process of retrogressive succession stops whenever these areas are brought under scientific grazing management and related measures such as fire protection; soil and water conservation etc. This sets into motion progressive succession which brings about an improvement in the condition of the grassland. A stable form of grass cover will develop if grazing is managed according to the needs of the land.

In the lower stages of succession, the grasses usually have a low fodder value and poor yield. As succession progresses; perennial, good fodder grasses of a higher nutritive value begin to dominate.

Grazing affects plant succession in the following ways :

(a) it causes mechanical injury to the vegetation.

(b) it brings about a change in the floral composition.

(c) it disturbs the physiology of the plants.

(d) it causes soil erosion, soil compaction and reduces infiltration.

Prolonged and overgrazing leads to the process of retrogression in which the plant community is degraded to lower levels of plant succession.

In the hills, retrogression may take place due to heavy or overgrazing followed by sheet erosion which gives birth to the formation of gullies. The vegetation is an indicator of the prevailing site condition. In such cases, restoring succession is a difficult task.

It is easier to adopt remedial measures in the plains if there is no loss of top soil by wind or water. Adequate protective measures such as fencing are likely to restore the succession to its normal course.

Stages of retrogression

Retrogression induced by overgrazing may proceed along the following stages :

(a) **Physiological disturbance** : There is a marked decrease in the growth and vigour of the preferred grass species. This is indicated by :

- reduction in height growth
- reduction in basal growth
- reduction in reproductive activity.

(b) **Changes in floral composition** : Overgrazing brings about a marked reduction in the population of the preferred species. The proportion of secondary, non-palatable species goes up. The species whose proportion increases are known as increasers and those whose proportion decreases are known as decreasers.

(c) **Invasion of new species** : With a continuous loss of vigour and subsequent changes in floral composition; there occurs an invasion of the site by species that were absent in the primary succession. However even at this stage, local centres of climax may be identified and protected in a way that they may serve as a nucleus for further development. The new species that invade are known as invaders.

(d) **Disappearance of original cover** : Continuous heavy grazing leads to the subsequent disappearance of the original vegetal cover even though it may continue to occur in a few isolated patches that have not been overgrazed.

(e) **Decrease in the density of invaders :** Prolonged overgrazing may lead to the ultimate decrease in the population of the invaders. This is an advanced stage of degradation in which even the invaders that came in at the earlier stages discussed above, begin to loose ground. The invaders give way to bare patches which lead to the formation of gullies.

CARRYING CAPACITY

Carrying capacity is the maximum number of animals that can graze on a specific area over a given period of time without causing any adverse affects such as a decrease in the production of fodder; forage quality, soil erosion etc. If the carrying capacity is fixed on basis of low production years then there is a likelihood of under utilization. On the other hand if it is fixed on basis of good production years, overgrazing may result. Thus, carrying capacity must be determined on basis of average production years.

Carrying capacity is invariably expressed on basis of an average production year. This is done to avoid over - or under - utilization

$$\text{Carrying capacity on animal basis (per hectare)} = \frac{\text{total number of animal days}}{365 \times a}$$

where a is the area of the grazing land in hectares. An average animal weighing about 400 kg needs about 8 to 10 kg of dry fodder each day. They also require about 6 to 8 litres of water per day depending upon age, kind of animal etc.

Arriving at the optimum number of animals that can graze in an area without causing any adverse influence is perhaps the most difficult problem in grazing management. Some factors which further complicate this problem are :

- variation in the annual production of fodder.
- variations in the total fodder consumption of animals.
- loss of soil by wind and water erosion.
- varying climatic conditions.
- variations in the floral composition of the grassland whose carrying capacity is being determined.

The following procedure is adopted for determining carrying capacity :

1. A detailed forage analysis is made with each grass species being listed; the percentage of the total composition that it represents is determined and the forage density of the plant type estimated. In certain cases only the important fodder species are analysed.
2. The weighted use factor is obtained by multiplying the use factor of each species by the percentage of the composition and summing up these products.
3. The forage index expressing the part of the range that is covered with the available vegetation that can be entirely devoured by animals without permanent damage, is determined. This is arrived at by multiplying the weighted use factor and the density of the type cover.

Thus, a hectare of land that is only half covered by palatable species (use factor 0.5) would have a forage index of 0.25 or equivalent to 1/4 forage hectare (acre). Forage hectare is a theoretical area covered entirely with grasses which are all

palatable to livestock. When this factor is multiplied by the total area of the type, the total forage hectare is arrived at.

The following two equations give a summary of forage hectare factor and forage hectares :

(1) Forage hectare factor = percentage species composition x use factor of each species x forage density of the type

(2) Forage hectares = forage hectare factor x surface area

The carrying capacity of various grasslands is shown below :

Grassland	Carrying capacity (cow units/year/hectare)
Cenchrus ciliaris	7 to 9
Cenchrus setigerus	9 to 13
Chrysopogon fulvus	6 to 8
Dichanthium	6 to 8
Heteropogon contortus	4 to 6

INDICATORS OF OVER GRAZING

Plants

The abundance of a number of plants is indicative of conditions of heavy grazing. Some species are :

Argemone
Opuntia sp.
Chrysopsis villosa
Poa pratensis
Nicotiana sp.
Euphorbia sp.
Lantana camara
Artemisia sp.
Munroa squarrosa
Potentilla sp.
Bromus rubens
Franseria deltoidea
Agave sisalana
Lepidium sp.

Soil conditions

Soil conditions are also indicative of conditions of heavy grazing. The following are some examples :

- severely eroded soils.
- leached soils.
- soils with a low nutrient status.
- soil compaction.

Removal of the soil from forests by water or wind is indicative of overgrazing and misuse. In cases where water is the eroding agent, sheet erosion takes place in the initial stages and this gives way to the formation of gullies. On steep slopes, gullies tend to appear soon after accelerated erosion sets in. This is an index of heavy grazing. A lot of information can be gathered from gullies on basis of the undermentioned characters :

- relative abundance; or density per unit area
- appearance
- condition of the gully banks
- speed with which it is enlarging.

Gully banks devoid of vegetation tend to cave in and increase the area and depth of the gully. However, if vegetation begins to establish itself on a gully bank, it may be said that the gully has begun to heal up.

Erosion of the soil by wind takes away the finer particles which are not held by the roots. This leaves behind soil particles under the roots of plants in the form of small islands. The size of these islands is an indicator of soil erosion which in turn reflects the heavy use of the pasture.

Livestock condition

The condition of the livestock grazing on an area is an indicator of the lands condition. The range condition is

satisfactory if the animals are healthy. Deterioration of the livestock means that the pasture has been subject to heavy use.

Effect of climate on carrying capacity

There is a close relationship between climate and the carrying capacity of the land. Amongst the various climatic factors, precipitation and temperature influence forage production to a large extent.

The production of forage is more in areas receiving a substantial quantity of rainfall. Pasturelands occurring in moist areas are able to produce more. On the other hand in tracts receiving less rainfall, the production of forage is immensely reduced e.g. in the arid tracts of Rajasthan, Haryana and Gujarat.

Prolonged spells of dryness are also detrimental to the production of forage on rangelands. Growth is immensely reduced during periods of drought. Overgrazing is more harmful to the pasture under such conditions. Decrease in the production of grasses is directly proportional to the intensity of grazing. Heavy grazing brings about a decrease in both the depth to which the roots are able to penetrate and the volume of root production.

For minimising the damage to plants during prolonged spells of drought the following steps should be adopted :

(a) Adequate provisions must be made in the range management plan for periods of drought, based on the climatic data of the previous decades.

(b) Carrying capacity calculated for ideal conditions should be reduced by about 20 to 30 percent.

(c) The period of grazing should be adjusted in a way that the area is not grazed during the harsh summer months when temperatures are very high and rainfall is very low.

SEASON OF GRAZING

Based on the season of grazing, pastures may be divided into two categories :

(a) **Annual pasture** : one of which animals graze throughout the year.

(b) **Seasonal pasture** : one on which grazing is allowed only during a particular period each year.

On annual pastures, animals remain for all 12 months and hence damage is more. Based on the season of grazing, seasonal pastures may, in turn be divided into two :

(i) **Winter pasture** : These pastures usually occur in the foot hill zone and are grazed by migratory livestock only during the winter months.

(ii) **Summer pasture** : These pastures usually occur in the high altitude areas and are grazed by migratory livestock only during the winter months e.g. alpine pastures in the Himalayas.

Seasonal migration is regulated by the following factors :

- snow
- quantity of forage available
- quantity of water available
- condition of the livestock
- loss of nutrient in drying forage
- growth vigour of spring forage
- soil condition e.g. soil moisture etc.
- injuries to which the grasses are liable.

Winter grazing starts when the livestock are forced by snow to migrate to areas of lower elevation from the summer grazing grounds. The plant growth slows down due to the extreme cold and this forces the cattle to migrate to warmer areas which may be in the foothill zone.

Spring and summer grazing starts when the snow melts; the soil is firm and the plants begin to put on rapid growth. During spring, the rapid growth of plants may temporarily deplete food reserves and hence, grazing may be deferred till the plants are able to restore these food supplies.

PLANNED GRAZING

Planned grazing is of paramount importance for the growth and well being of a pasture land. This may be of the following forms :

(a) **Continuous grazing** : In continuous grazing, the livestock graze upon a particular area all through the year. The animals have free access to all parts of the forest and the range use follows the same plan each year.

(b) **Unitary grazing** : In this form of grazing, only one type of animal is allowed to graze upon a forest e.g. in areas where the growth is slow or where larger animals are likely to cause more damage; only goats and sheep may be allowed to graze.

(c) **Mixed grazing** : In this form of grazing, all types of livestock are allowed to graze upon a forest. Mixed grazing is allowed in healthy and well protected areas.

(d) **Deferred grazing** : This form of grazing pertains to delayed grazing. In some cases, the longer the beginning of grazing on a particular forest can be delayed; the better it is for the

young plants to establish themselves and for the older ones to put on the requisite growth. In deferred grazing, the beginning of grazing is delayed till the important palatable species have completed their reproductive cycles and the new individuals have established themselves. Thus, the season of the beginning of grazing may vary from pasture to pasture.

Deferred grazing has the following advantages :

- if the beginning of grazing can be delayed once every few years then the palatable species have a better chance of reproducing.

- delayed grazing is immensely beneficial for plant species which reproduce by vegetative means. It helps in the production of rhizomes and other vegetative parts.

- by allowing individuals of the preferred species to grow undisturbed during a period most favourable for their growth, a larger quantity of seed is produced.

However, delayed grazing is not always very beneficial for the pasture. It must be adopted carefully and only those measures which are absolutely necessary should be taken up.

(e) **Rotational grazing** : This is perhaps the most rational form of grazing. The forest to be grazed is divided into a number of units each of which are opened for grazing in turn. Thus, while one unit is being grazed, the other units of the same forest are closed to grazing and are able to put on vigorous growth.

Rotational grazing is based on two assumptions :

- a large number of animals per unit area means a more uniform use of the forage.

- a rest from grazing is beneficial for the plants.

Some advantages of rotational or alternate grazing are :

(a) The damage by trampling is considerably reduced because a large number of animals are concentrated in a small area and are unable to move about freely.

(b) The fodder is utilized uniformly.

CHAPTER 18

PROTECTION AGAINST WILD ANIMALS

Wild animals are an integral part of the forest eco-system. They co-exist with the vegetation usually in a harmonious relationship. However once the balance of nature is disturbed, the impact of wild animals on the forest vegetation is seen. They may cause physical or physiological damage to the trees and the forest ecosystem as a whole.

Hundreds of species of wild animals live in India's forests varying from the small field rat to the elephant, the largest terrestrial animal in the world. These may be classed into the following:

1. **Carnivores**: This group of animals feed on other animals e.g. tiger, leopard and even the cat. They occupy the apex of the ecological triangle and help to keep the population of the herbivores in check.

2. **Herbivores**: These animals feed on vegetative matter such as leaves, flowers, fruits, branches, twigs and seeds. The important herbivores are deers, antelopes, wild goats, elephant and rhinoceros. Herbivores cause more damage to trees than carnivores. Their population too is more as compared to the former.

1. ELEPHANTS

As has been mentioned in the above text, the elephant is the largest terrestrial animal. In India elephants are found over a wide tract in the Himalayan foothills, north-east India, east-central India and south or peninsular India. They usually live in herds whose size varies from 8 to as many as 30, though solitary or rogue elephants too are found. Due to their size these animals need a considerable quantity of food and this causes adverse effects on the trees of the areas in which elephants may choose

to feed. The herd may strip the foliage of the trees of an area thus causing considerable problems.

The adverse effects of elephants on trees and the forest ecosystem has been discussed in the following text:

(a) The vegetation occurring on the forest floor is trampled upon under the feet of elephants. This includes the seedlings and saplings of the favoured species.

(b) Elephants feed on trees and poles may be uprooted by them after feeding, thus hampering the establishment of regeneration.

(c) A vast quantity of leaves and branches are eaten by the elephants thus affecting the productivity of the forest, opening gaps in the canopy and affecting the process of regeneration when the flowers and seed are also eaten.

(d) Elephants strip the bark of species like *Artocarpus* and *Shorea robusta* (sal), thereby causing permanent damage.

(e) Elephants also cause immense damage to forest plantations and nurseries. They eat the young trees and uproot others thereby causing loss of both money and effort that had been put in to raise and maintain the nursery and plantation.

(f) They also destroy forest buildings, telephone poles, boundary pillars and fences. Elephant herds moving in a particular area may also hinder forestry operations.

Preventive and control measures:

The following preventive and control measures may be taken against damage by elephants:

(i) Anit-elephant trenches or ditches dug around areas to be protected are the cheapest way to prevent damage by elephants. These are wide and deep ditches dug in a way that elephants are unable to cross them

(ii) Another method is to beat drums or fire guns in the air to scare away elephants.

(iii) Nowadays electrified fences are also being put up to keep away elephants from a particular area.

(iv) Forest tracts damaged by elephants may be rehabilitated by plantings and sowings so that there are no permanent gaps in the canopy.

2. BISONS AND WILD BUFFALOES

Bisons and wild buffaloes are found in many forest areas of India. They move in herds and may cause considerable damage to the forest ecosystem. These have been discussed in the following text:

(a) Bisons tend to strip off the bark of certain species such as *Acrocarpus fraxinifolius*. As a result the physiology of the tree is adversely affected.

(b) They browse the seedlings and saplings of the desired species thus hampering regeneration.

(c) Herds of bisons and buffaloes may trample upon the young regeneration of the favoured species.

(d) These animals also cause mechanical damage to the seedlings, saplings and poles of the favoured species.

(e) They may also enter forest nurseries and plantations and cause considerable damage.

Prevention and control:

The following measures may be adopted for the prevention and control of damage done by bisons and wild buffaloes:

(a) Digging trenches so as to prevent the entry of these animals in the areas to be protected.

(b) Firing of guns and crackers and beating of drums to scare away herds of bisons and wild buffaloes.

(c) Adoption of damage control measures such as plantings and sowings in gaps and also removing the individuals damaged by these animals.

3. WILD PIGS

Wild pigs or boars are very widely distributed in India. They live not only in the forest areas but also in the adjoining tracts. Very often these animals cause considerable damage to both forests and agricultural fields. Though this animal is omnivorous it is extremely fond of the young and succulent roots and tubers of plants. The adverse effects of wild pigs to forests have been summarised below:

(a) They readily eat the roots and tubers of many species which are dug up from the soil.

(b) While digging the soil the wild pigs expose or even damage the roots of the favoured species thus hampering regeneration.

(c) They are fond of eating the germinating sal seedlings which may also be uprooted in the process.

(d) In the hills wild pigs tend to girdle the deodar and cypress trees thus affecting their physiology. They are more likely to damage poles.

(e) Wild pigs are extremely fond of the rhizomes of bamboos which they readily dig up thus destroying large clumps of bamboos both natural and planted.

(f) These animals may cause widespread damage to all types of forest plantations and nurseries. They dig up the succulent roots of the young plants in plantations and nurseries. These animals also eat the young shoots of the favoured species.

(g) The habit of these animals of digging the soil is very damaging to the forest ecosystem and hampers the process of scientific management of forests.

Prevention and control:

The measures adopted for preventing and control of damage by wild pigs have been discussed below:

(i) Special fences are erected as protection against wild pigs. These are provided with a wire mesh that is buried into the soil in order to prevent the wild boar from digging beneath the fence.

(ii) Guns may be fired in the air or crackers used for scaring away these animals.

4. DEERS AND ANTELOPES

Many different species of deers and antelopes are found in the forests of India. Amongst them are spotted deer, blue bull, sambhar, hog deer, swamp deer etc. These animals usually live and feed in herds, thereby causing considerable damage to

trees and the forest ecosystem. The adverse effects caused by deers and antelopes have been outlined below:

(a) They may readily devour the seedlings of the favoured species. Sal seedlings are eaten by cheetal and sambhar thus having an adverse effect on regeneration. In the summer season, when most shrubs are dry, the sal seedlings remain succulent and hence are largely eaten by these animals, resulting in their death or at least slowing down of growth.

(b) Sambhar and cheetal also have a liking for the young individuals of many other species such as *Albizzia lebbeck, Artocarpus chaplasha, Chloroxylon sweitinia, Dalbergia latifolia, Hopea, Morus lavegata* and *Ptreocarpus marsupium*. They eat the tender leaves and shoots of these species.

(c) Deers also rub their antlers while in velvet against the poles of different trees which may belong to the favoured species such as sal. This exposes the cambium making them prone to attack by fungus and insects.

(d) Some deers like sambhar also tend to strip the bark of trees (sal) thereby causing physical damage and adversely affecting the physiology of the trees.

(e) Deers and antelopes also cause damage to forest nurseries and plantations.

Prevention and control:

The prevention and control measures commonly adopted include:

(i) Erecting special fences for preventing the entry of deers and antelopes into an area.

(ii) Using electrified fences in which a low intensity current is constantly passed.

5. BLACK BEARS

In the Himalayas, black bears damage the poles of deodar, blue pine and spruce by stripping off the bark to suck the sap. This has an adverse effect on regeneration. Fencing off areas with pole or younger crop is an effective way of preventing this form of damage.

6. MONKEYS

Monkeys and langurs eat the fruits and seeds of the desired species thus affecting regeneration. They also uproot saplings in plantation areas and seedlings in the nursery. Damage by these animals is prevented by firing crackers to scare them away.

7. RODENTS

Rodents causing adverse effects on young regeneration of the favoured species include porcupines, hares, rats and squirrels. They eat the seeds and fruits and also the succulent shoots and roots of seedlings. Rats extensively damage bamboos particularly when they are flowering.

Damage from rodents can be prevented by erecting special fences with underground wire meshes.

8. BIRDS

Birds eat the fruits and seeds of the favoured species both in forest areas and in the nursery. Nurseries may be protected from damage by birds in the following manner:

(a) Covering the beds with wire nets

(b) Using scare crows to keep away birds

(c) Firing blank cartridges and crackers

CHAPTER 19

PROTECTION AGAINST PLANTS

Though it sounds strange plants too have certain injurious effects on forests and the forest ecosystem. Certain types or groups of plants cause considerable damage to trees and forests. These may be members of the favoured or desired species or may be unwanted ones with little direct benefit either to the forest or human beings.

There may be adverse effects on forests by over population of the favoured species or the undesired species may cause injury to the forest or they may even have adverse effects by blocking light particularly for the young regeneration, suppressing the saplings or offering stiff competition for food and water.

This chapter deals with the injurious effects of plants and various methods of protection against them. The injuries caused by plants may be classed into the following-

excess of favoured species or over population

excess or unwanted species or over population. These include weeds, parasites, epiphytes and climbers.

I. EXCESS OF FAVOURED SPECIES

In usual forestry parlance the favoured species usually refers to that species or group of species whose growth is desired for meeting the broad objects of forest management be it commercial, recreational, ecological or for fulfilling the daily needs of the local population.

In the early stages of formation of a forest, the population of the favoured or desired species is usually much more than the bearing capacity or what is required. This holds true for forests regenerated from different means such as natural seedings plantings, sowings or even coppice. The number of saplings or coppice shoots is more than what is required or will survive once the forest becomes established. Under natural conditions too where regeneration is an ongoing process, the number of saplings or seedlings is much more initially. This situation has been described as over population and it occurs both for the favoured and unwanted species alike. Over population of the favoured species is harmful in the following manner-

(1) The supply of essential requirements for plant growth such as food, water, minerals etc. is restricted.

(2) The quantity in which these requirements are needed increases manifold as the plants grow older. Thus the competition becomes fiercer and fiercer.

(3) The better growing or healthier members of the favoured species tend to suppress the weaker members of the same species.

As a result the over-population of the favoured species leads to the problems listed below-

- congestion in the crop
- reduction in growth vigour of the favoured species
- renders the trees particularly the younger individuals susceptible to attack by diseases and insects.

The adverse effects caused by over-population of the favoured species may be prevented/controlled by the following measures-

a. Timely thinnings

b. Periodic removals of weak and diseased individuals of the favoured species and also those which have been attacked by insect pests.

c. In the case of plantations the spacing should be such that there is no problem of over-population.

II. EXCESS OF UNWANTED SPECIES

There are many different groups or categories of unwanted species that cause adverse effects on forests and trees. These have been discussed in the following text:

A. WEEDS

Weeds are a group of herbaceous or shrubby plants that appear on the forest floor particularly much before the seedlings of the desired species have established themselves. They have to be checked or else they cause considerable damage. The problem of weeds is also acute in forest nurseries where regular weedings have to be carried out for keeping the beds free from weeds.

Both direct and indirect adverse effects are caused by weeds. These have been listed below:

(1) Matted roots of weeds hamper the establishment of regeneration of the favoured species eg couch grass and bulberry.

(2) Weeds tend to use mineral nutrients essential for the growth of plants thus making it difficult for the young regeneration to survive e.g. potassium and phosphate.

(3) There is also mechanical injury to the seedlings and saplings of the favoured species from weeds particularly in the case of slow growing species.

(4) There is immense competition for moisture, light and essential nutrients between weeds and young individuals of the favoured species. This becomes significant in the arid and semi-arid areas.

(5) Weeds cause the retention of a large quantity of rain water on the soil surface in the monsoon season thus lowering the level of infiltration into the soil.

(6) They cause the formation of swamps. As a result there may be waterlogging, change in the ecology and occurrence of frost in the cold season.

All peat plants increase the swampiness of the soil.

(7) A dense growth of weeds or grasses in a forest prevent dew or light rains from reaching the soil. The moisture merely wets the leaves of the weeds growing densely. Thus the seedlings of the favoured species may be deprived of the benefit of this moisture more so in times of drought or in arid areas where every drop of moisture is important for the establishment of regeneration.

This becomes apparent when the soil is dug up and the layer just beneath the surface examined.

(8) Weeds also draw up the precious moisture from below the surface and transpire it into the air.

Thus they contribute to general aridity of a region.

(9) A dry humus is produced by some weeds which is not suited for many forest species.

(10) On drying, the dense growth of weeds increases the danger of forest fires.

(11) Weeds also serve as hosts to injurious fungi which then damage forest trees and agricultural crops.

Weed damage to various tree species:

On the basis of damage suffered by various species from weeds they may be classed as shown below:

a) **Suffer much** : The species which suffer much due to weeds include willow, oaks, chestnut, fir and spruce.

b) **Suffer less** : This includes species like birch

c) **Suffer lesser** : In this category lie species like chir pine and *Shorea robusta*.

d) **Suffer least** : The species which suffer least from damage by weeds include *Robinia pseudacacia, Pyrus pashia, Prunus padus, Acacia catechu, Prosopis* and sisham.

Abnoxious weeds:

This is a common name given to weeds which cause severe damage to forests over a large area. They suppress natural regeneration on a large scale, offer stiff competition to trees upto pole stage and even constitute a fire hazard. They are very difficult to eradicate and spread at a fast pace.

Two abnoxious weeds have invaded many forest areas of India. These are- a) *Lantana camara* and b) *Eupatorium*. Amongst them the former was introduced into the country as an ornamental and hedge plant. However within a very short time it spread to forest areas, pastures and even agricultural fields damaging vast tracts of useful land. Many different methods have been adopted for preventing the spread and controlling this weed. Research has even been carried out to find economic uses of this weed so that it can be put to good use. However the problem evades solution and many forest areas continue to be damaged by these weeds.

Prevention and control:

Many different methods have been adopted for the prevention and control of damage by weeds to forest areas. These include:

(1) The most common method is to physically cut the weeds as frequently as required. This is done manually in forests.

(2) Before taking up an area for plantation all weed growth is removed manually or even mechanically where possible if the area to be planted is large. The soil may be turned over with a buldozer or tractor pulled plough so as to remove the weed growth.

(3) Regular weedings are required in the nursery so as to remove the weeds as soon as they appear. In polybags containing seedlings, weeds have to be removed. The frequency in which this is to be done varies with local conditions. In some areas labourers have to carry out weedings continuously, moving from one bed to the other in a sequence.

(4) Burning is another method used for the eradication of weeds in forest areas particularly if

the area to be tackled is vast. This is done with the help of a low intensity fire so that only the weeds are burnt and the flames do not become uncontrolable.

(5) Chemicals are also now widely used for the eradication of weeds. These are known as weedicides, different types of which are available on a commercial basis e.g. dalopan;2, 4, 5-T; 2, 4-D; gramoxone and reglone. These chemicals lead to the death of the weeds. They are usually sprayed over the area affected by weeds or in some cases may have to be applied individually to the unfavoured individuals.

(6) While preparing the soil mix for use in nursery beds or containers, weedicides may be mixed with the soil in minor quantities. This is a fairly successful way of preventing the occurring of weeds in forest nurseries.

B. PARASITES AND EPIPHYTES

Parasites are a group of plants which grow on the host trees and draw their food from them by penetrating their roots known as haustoria into them. Within a short span of time parasites may cover the entire tree which often may be the favoured species.

The adverse effects caused by parasites are-

(1) They weaken the host plant and render them susceptible to attack by insect pests and diseases.

(2) Parasites share the food drawn or manufactured by the host plant.

(3) They may even lead to the death of the host plant more so if the latter is young and weak and the parasite attack is very severe.

The following measures may be adopted for preventing and controlling damage from parasites:

(a) They are physically cut off or removed form the individuals of the favoured species. However this cannot be done if the parasite infestation is over a large area.

(b) Parasites may be burnt down

(c) Chemicals are also used for the eradication of parasites.

Epiphytes live on the host plant but do not depend on the for host their food. The adverse effects of epiphytes are-

- they weaken the host plant

- they outgrow their hosts and may even lead to the death of the weak and young ones.

The adverse effects of epiphytes may be prevented and controlled in the following manner-

(a) Physically cutting them down or removing the branches on which they may be growing.

(b) By burning the epiphytes

C. CLIMBERS

Climbers are a group of non-woody plants which depend on other plants for support as they cannot remain erect themselves. The adverse effects of climbers are summarised below:

(1) They are extremely harmful to young regeneration as they may completely cover the latter causing mechanical injury.

(2) Climbers compete for light, food and moisture with the favoured species

(3) Over the years as the tree grows climbers may make permanent grooves in the timber thus reducing, its commercial value.

(4) They may hamper regeneration by preventing light from reaching the forest floor.

(5) Climbers add to the risk of forest fires

(6) A profuse growth of climbers may bend young stems of the favoured species.

Prevention and control:

The following measures may be adopted for the prevention and control of damage due to climbers:

(a) When the climbers are young and tender it is advisable to trace out their roots and pull them out. This can be readily done when the soil is wet and soft.

(b) Thicker and woody climbers may be cut at two points, one near the base and other at a height of about 1 mt so that they die off. This may be a part of the regular cultural operations and done in areas with a heavy incidence of climbers. This may be repeated after 3 to 5 years. Climber cutting is a part of regular forest management.

(c) Weedicides and poisons are used to kill well established climbers. These may be sprayed on the leaves or on the basal portion after climber cutting.

CHAPTER 20

INSECT PESTS

Insect pests are a major problem in natural forests, plantations and nurseries and the forester is required to prevent and control the damage done by them.

PRINCIPLES OF PREVENTION AND CONTROL

The most important thing in the control of pests is the early detection and prompt report to exports for advice. A control measure may be direct or indirect in its action on the pest, or its may be preventive or remedial. The most important thing in the control of a pest is its early detection and prompt report to experts for advice. For purposes of forest protection control methods are :

(1) Silvicultural control

(2) Biological control

(3) Mechanical control

(4) Chemical control

It may be noted that it is impossible in actual practice to exterminate a forest insect pest. The object of artificial control as opposed to natural control is the regulation of the numbers of the pest to the level at which the damage done by it is within financial tolerance. In other words if the loss is considered as an inevitable accompaniment of the objects of forest management, the pest then may well be said to be under economic control. Under conditions of economic control fluctuate considerable below the level at which it becomes a pest.

1. SILVICULTURAL CONTROL

By silvicultural control is understood the regulation of the abundance of a forest insect species by factors of silvicultural practice. Silvicultural practice may be designed and employed so

as to obtain the economic control of an insect pest, but it works independently of any intention on part of the forest officers and some times unappreciated by him. If a forester converts a previously harmless insect into a pest by an application of silvicultural measure, the pest can only be prevented from doing intolerable damage by measures of a similar order to those that created it.

Pure stands (regulation of forest composition affecting food supply, quantity). (i) Pure stands offer the most favourable conditions for the multiplication of pests because the area gives the maximum quantity of food supply (ii) the pest in all stages has little difficulty in finding food supply and breeding material (iii) abundance of natural enemies-parasities of nesting or insectivorous birds. Thus pure even aged plantations or forests under the uniform system are liable to serious damage by insect pests. All the major pests of Indian Forestry are most injurious in forests of this class; example (1) behole borer of teak *Xyleutes ceramicus*, teak canker grub (*Dihamus cervinus*) defoliator (*Calopopla leavane*) the phassus borer (*Phassus malabaricus*) champaca bug (*Drastylus punetigera*) teak defoliators (*Hapalia machaeralis* and *Hyblaea purema*) are all plantation pests and rarely so in natural forests. The set up of natural and virgin forests is completely upset in a pure stand and forces pest outbreaks in such areas. Retention of natural strips of forest areas is of fundamental importance in pure stands.

Mixed forests

The value of mixtures in protecting the principal timber species in the crop lies in the following advantages :

(1) reduction in the quantity of food supply available to the pest in the area;

(2) varied food and suitable shelters are made available for parasites and predators that are maintained at a high level owing to the existence of alternate hosts;

(3) insectivorous birds get a continued food supply throughout the year;

(4) mechanical observation is offered to the dispersal of crawing defoliators (larvae) that drop to the ground from crowns and try to reclimb the trees, and they die out of starvation; mechanical obstruction is also offered to the flying adult insects in finding the food plant of choice. In case of epidemic no type of forest composition mixed or otherwise will be effective in preventing attack, example teak defoliators, sal heartwood borer. There is one important point for consideration that alternate food plants of pests of the main plant species in the mixed forest should at all costs be eliminated since its existence or retention affect the food supply; both in quantity and quality, which is really undesirable; example - (1) presence of *Premna latifolia* and *Vitex negundo* is harmful in teak defoliator *Hyblaea puera,* (2) similarly *Callicarpa lanata* is alternate food plant of *Hypalia machaeralis* and is undesirable in a teak plantation. *Clerodendron infortunatum* is undesirable in young teak plantations as it is the natural food plant of teak canker grub *Dihammus cervinus*. Some species are initially pests of climbers to main timber species and later on pass onto the timber species and thus climbers are to be discouraged.

Thinning

Abrupt thinnings at longer intervals is undesirable; gradual thinnings at smaller intervals does not interfere with the natural balance between the pest, parasites and plant community. Thinnings should as well improve the forest insect hygiene, taking due notice of dead and diseased trees, wounded trees, trees dying and weaker from loss of vitality, accumulations of slash. All these must be removed an disposed off and burnt if necessary.

Density

Density of the crop influences the physical conditions by modifying the intensity of light, evaporation, air, environment and fluctuations of temperature. All these factors indirectly affect insect life in forest for example - (1) toon shoot borer and the semul shoot borer (*Hypsipyla robusta* and *Tonica niviferena*) in these two cases the density of the crop determines the ability of the tree to outgrow the injury. (2) Excessive density may be harmful with some pests.

Epicormics increase defoliation and defoliation increases epicormics. Many tree species produce excessive epicormies with excess of light.

Regeneration areas

Regeneration by small areas is advantageous since it restricts food supply of pests. Regeneration approaching natural process achieves immunity from insect damages. Artificial regeneration suffers more than natural regeneration. Where artificial regeneration follows clearfelling, damage by insects is greater than if regeneration is established under a shelterwood. It is advised to regenerate an area annually by breaking up into small separate coupes in several felling series and allowing age-classes of wider variations to grow amongst the crops regenerated. Repopulation of a large clear felled area by immigrant plant eating species occur as soon as their food supply becomes available but repopulation of the same area by their natural enemies is a much slower process.

Very small centres of artificial regeneration in the form of gap-fillings surrounded by mixed forest are liable to severe damage; the patches are invaded from the surrounding cover by grasshoppers, crickets and cutworms which attach to the seedlings or transplants above ground, and the soil fauna (consisting of cockchafters, wireworms, crickets etc.) deprived of their normal food supply attach to the roots of the seedlings. The young saplings flushing in the light that does not penetrate the

surrounding forest are very attractive to host of polyphagous defoliators and sap suckers; patch sowings of this nature of *Cedrus deodara, Tectona grandis, Dipterocarpus,* and many other species tried in small plots in evergreen and rain forests are liable to severe damage.

Fire

The effects of fire can be considered from the aspect of burning and fire protection.

(1) **Burning** : Burning of refuse in clear felled areas prior to artificial stocking destroys all the insects and small animal life that are unable to fly or run at the time of burning. The result is that the area is cleared of pests and as well as all beneficial or harmless members of the community are exterminated. Subsequently repopulation by plant feeding forms occurs first. Natural enemies parasites and predators cannot exists so long as their hosts are not abundantly established. Thus in crops the equillibrium is disturbed in favour of the pests. Subteranean fauna living at depths below few inches of the surface soil remain unharmed. The result is that after the burning all the subtaranean inhabitants successfully emerge example teak canker grubs *Clerodendron infortunatum.*

Controlled burning in high forest destroys many of the free living animals mice, lizards, etc. and kites, hawks later feed on their corpses; insects in the canopy or high up in the trunk drop to the flames. Under no ordinary circumstances is it wise to use ground fire as a remedial measure for an insect epidemic.

(2) **Fire protection**

The exclusion of fires from forests previously exposed to periodic burning has far reaching effects, i.e., it permits tree growth in deciduous forests, fire-tender species, particularly the evergreens are protected and a forest occurs but scrub-growth protected thus invade forest trees, example the temperature montane scrub to *Pinus excelsa.* The direct effect of continuous fire protection on animals is marked by the increase and

performance of animal populations and particularly of the natural enemies of insect pests. It assists in the stabilization of the flora. Reliable evidence for or against fire protection as having assisted in insect-epidemic is none on record. The case of beehole borer of teak offers incidence increased under fire protection (during the 30 years or so); ecological consideration suggest that fire as a factor favours increase of the borer.

Selection of resistant varieties and species

Indulgence in the production of insect resistant tree varieties is the sphere of geneticists, and forest genetics study is as yet in the nursery stage.

2. BIOLOGICAL CONTROL

In modern usage biological control means the employment of natural enemies and diseases of a pest for the purpose of maintaining economic control. It is not confined to the utilization of parasites only. In forestry biological controls are used in conjunction with the silvicultural control and may be regarded as an extension of the same. In forestry tree biological methods may be utilized :

(i) mass production and release of selected parasites and predators as a regular annual operation.

(a) egg parasite, the world famous *Trichogramma evanescens*, has been introduced in large masses in sugarcane fields which are subject to the attacks of various kinds of borers, particularly the topshoot borer, in Mysore. This operation has resulted, according to the claims, in the substantial increase in the yield of sugarcane.

(b) *Microbracon brevicornis* is used similarly for the control of pink-bollworm of cotton

in the Punjab, *Microbracon grechni* and other species against the predators *Eublemma emabialis* and *Holeocera pulverea* in Bihar.

(c) In forestry *Cedria paradoxa* has been released in masses in teak plantations in south India i.e. of Nilambur plantations against the principal teak defoliator (the skeletonizer) *Hapalia machaeralis* and in the Punjab against the shisham defoliator.

(ii) importation and colonization of species that are not indigenous. This is a non-recurrent operation.

(a) the natural enemy complex of an indigenous pest is incomplete in a particular locality owing to the absence of certain efficient species of its parasites or predators, and

(b) it is advantageous to restore the missing elements. Introduction on these lines have been made with teak defoliators parasites, (i.e. *Apanteles malevclous, Cedris paradox, Dioctes gardneri* in South India and Myanmar) Shisham defoliators (i.e. *Anthia sexguttata, Deiphobe incise, Diosphrys, sissoo, Microgaster placonterae* in the Punjab).

(iii) improvement in the environmental resistance to the pest by modification of plant community. Measures designed to increase the environmental resistance to a pest can only be used when the crop is grown on a long rotation as is in forestry (not applicable in agriculture). Given the exact data on the plant associations of

a timber species and its pests one can formulate a mixture (i.e. form a synthetic forest of choice) which will afford the maximum protection to the timber crop in any climate or on any soil. It can be obtained by encouraging or introducing the desirable plants and eliminating the undesirable or neutral plants with methods that are practicable such as selective weeding, thinning and under planting. According to their value in biological control the plants in a forest or plantation can be classified into the following categories from the entomological point of view :

(a) Plants that support insects that are alternative hosts of the parasites and diseases of the pest of the main crop. These are plant species that the entomologically useful and should be encouraged. A reserve force of polyphagous parasites is maintained to fight out the pest at any population level that increases suddenly or gradually.

(b) Plants, like above, which support insects that are part of the varied die of polyphagous predators that also feed on the host. Predator studies have not been extensively done as with parasites.

(c) Plants, like above, or not in the above two categories, that provide suitable shelter, nesting and breeding facilities, to birds, spiders, lizards etc. Such species of plants should ordinarily be retained along the boundaries of regeneration areas, along the drainage lines, along coupes marked for clear felling or thinning, and should be fire protected.

(c) Plants, that are entomologically undesirable in plantations, since they form the alternate food plants of pests feeding on the main crop. These should be eliminated.

(d) Neutral plants, that are neither desirable or undesirable, need not be encouraged for space occupied by such plants can better be utilized for the crop or desirable species.

Achievements in Indian forestry with biological control

In America and other countries biological control is a success and each year thousands of rupees are spent as a recurrent measures. In Indian forestry investigations have proved that maintenance of natural undergrowths composed of tree species contribute in the of biological control of pests. This is with particular reference to the biological control of teak defoliators.

The severest epidemics of teak-defoliators cause a loss of Rs. 130 thousand per acre in a fully stocked first quality plantation, normal defoliation destroys about 12% of the increment, i.e. an annual loss of Rs. 20/- to 25 thousand per acre. This loss does not include depreciations from epicormies and forking of the bole. During the last 20 years or so the general improvement in the Nilambur teak plantations has reduced losses to above 85% of the initial month i.e. an average annual gain to the extent of about Rs. 50,000/-. This is a permanent gain and biological control is essentially a non recurrent expenditure after its establishment.

3. MECHANICAL CONTROL

In forestry, the following mechanical measures are tried :

(i) Racking and compacting the humus to eliminate oviposition (chaffers etc.)

(ii) Sticky bands to trap or work as barriers to insects climbing the trees (deodar defoliator, moth, shisham defoliator, salix defoliator etc.)

(iii) Hand collection of egg masses, caterpillars, beetles, hagworms during hibernation (gamhar defoliator, salix defoliator, chafer, grubs crickets in beds etc.)

(iv) Traping (sal heartwood borer, mahaboney collar borer) sinking earthen pots flush with the ground in nurseries, light-trap, trap by baiting.

(v) Flooding, burning, trenching, crickets in nursery, grass-hoppers etc.

(vi) Burning and charring.

(vii) Barking (against bark borers, salai and other serious sap and heartwood borers)

(ix) Sack banding and pruning (toon and semul shoot borer, etc.)

(x) Repellants and attractants.

4. CHEMICAL CONTROL

Following are some of the chemical measures adopted :

(i) **Wood borers in storage**

Debarking, prophylactic insecticides DDT, BHC etc., preservation under pressure with creosote and others, existing infection by sterilization.

(ii) **Termites**

DDT, BHC to kill colony in mounds, soil poisoning to keep off termites; use of resistant

varieties of timber that are naturally resistant; special measures in buildings etc.

(iii) **Tree poisoning**

Sodium arsenite, ammonium sulphanate, sodium silicoflouride, etc. in paste form.

(iv) **Defoliators, sapsuckers**

Spraying and dusting contact or stomach insecticides.

(v) **Stored products**

Fumigation with carbon disulphide dischlorobenzene, etc.

(vi) **Sprays** :

Crude oil emulsion, kerosene oil emulsion, nicotine solution, DDT, BHC, soap solution (contact poisons). Neem leaf extract, paris green, arsenates (stomach poisons).

(vii) **Repellents** :

Derdeaux mixture, mosquito ointment.

(viii) **Fumigants** :

Carbon disulphide, calcium cyanide, naphathalene, dichlorobenzene.

(ix) **Wood preservatives** :

Creosote (Standard wood preservative) fuel oil, boric acid, sodium fluosilicate, zinc chloride.

(x) **Sticky bands** :

Tar-pitch oil (coaltar, pitch, dry soap, castor oil, earth, in the proportion - 37.5 : 7.5 : 10 : 12).

5. STATUTORY REGULATIONS

Quarantine measures, issue of certificates after due inspection.

NURSERY PESTS

1. COCKCHAFERS (WHITE GRUBS)

Adults feed on trees at dusk, do not fly by day. Eggs are laid in soil, deep; larva, 2" white grub, C-shaped, feeds on the small roots of plants, at times most injurious in seed beds and in cultural operations, seedlings are killed. i.e. Larval period 8-10 months, in cold and dry hot weather larvae go deep in soil and come within a few inches of soil surface during wet and cool weather.

CONTROL

(a) **Digging and Hand Picking**

During preparation of seed beds pick up grubs alongwith stones etc. and destroy the grubs. Take similar care in taungya operations so that from field crops they do not cross over to the trees.

(b) **Sowing**

Do not prepare seed beds in hot weather or beginning of monsoon since this period forms the egg laying season and loose earth facilitates oviposition. Sowings should be done in autumn, spring, winter when beetles are not on wing.

During oviposition the sowings can be protected either by (i) preparing the beds a month earlier to the swarming of beetles and compacting the soil-larvae by watering and patting, and sowing seeds by least disturbing the soil; (ii) or before the beetles swarm, cover the surface and sites of the prepared bed with a charcoal etc., and removing the same along the lines only when the seeds are sown; after the swarming period of beeties

the protective layer can be removed. If sulphur is cheaply obtained, dust it with 300 lbs. per acre of beds, instead of sand etc.

In permanent nurseries where chafer damage is always expected cover with 1/2" plank or wire netting frames. The beds should be edged with planks as deep as possible to prevent the outside grubs from wandering into beds (where termites occur pressure treated planks should be used).

(c) **Weeding**

Do not undertake weeding operation during the flight period of chafter beetles.

(d) **Transplanting**

If transplanting is to be done before or during the flight period, the empty beds should be protected against oviposition by methods as stated under sowing above. If the beds are not immediately utilised they should be sprayed with crude oil or kerosene emulsion. After the application of emulsion, normal watering should be done so that the insecticide penetrates deep into the soil.

(e) **Trapping**

Trap the wandering grubs at night by sinking earthern pots flush with the soil surface between the beds.

(f) **Soil poisoning**

This is possible in dry weather and applicable in small scale so as to kill the grubs in soil where seedlings or transplants are growing or observed to be withering.

(i) **Carbon disulphide**, naphthalene, acetic acid, and synthetic insecticides (DDT., BHC).

(ii) **Carbon disulphide** : Highly inflammable expansion needs special handling; dig deep holes with crowbar, 4 holes to a sq yd and pour carbon disulphide and close the hole. Soil will get fumigated; carbon disulphide emulsion has a much lower insecticidal action.

(iii) **CaCN** : Make furrows 4" deep between rows of seedlings and sprinkle dust along the furrow @ 3 oz per sq yd, fill in furrows with soil.

(iv) **Naphthalene** : Young grubs could be killed by naphthalene crystals @ 5 lbs per cu yd provided the soil is moist but not wet, free from lumps and undisturbed for about a week. It decomposes in soil in about 2 weeks. Mixing naphthalene crystals with top soil at about 1000 lbs per acre prevents oviposition but does not prevent beetles from burrowing deep into the soil.

(v) **Acetic Acid** : Conifer seed beds in particular treated with 0.8% acetic acid @ 3/4s of a quart per sq ft of seed bed is effective in preventing damage by white grubs. One to two application is sufficient, applied in the middle of the growing season. Acetic acid is efficient, inexpensive, readily transportable, harmless to seeds and seedlings, and also checks damping off.

(vi) **Synthetic insecticides (DDT, BHC)** : Use of synthetic insecticides is recent discovered; soil dressing is recommended with dusts and water-suspension powders should be given gamma-BHC 0.5% to 1% and DDT 5% to 10% is a recommended dosage.

2. CUTWORMS (SURFACE CATERPILLARS)

Cutworms are pests in nurseries and regeneration (artificial and natural) in forests; a polyphagous pest of agricultural

and garden crops. Conifers are most susceptible to cutworm injury, plants being cut off at ground level after germination (particularly in March-April).

Female lays eggs early in summer in humus, stones, weeds and other plants (2000 eggs are laid by one female); prefers moist situations, wet soil, mud etc. The cutworms feed an dry leaves forming soil cover (they are also carnivorous in habit) hide in burrows 3" deep in soil during day. At night they cut seedlings through the stem at ground level; larva, if disturbed, curls into pupation; larval period 20 to 35 days, and pupal period 10 to 30 days.

CONTROL

(a) **Seeding**

Grasses and weeds are undesirable.

(b) **Irrigation**

Flood the area and force the larvae out of their tunnels in soil and kill as they come on the soil surface.

(c) **Collecting**

Collect and kill larvae, after rains taking shelter in soil, under debris, leaves, stones, etc. Digging in early winter exposes hibernation cutworm larvae to frosts.

(d) **Poison baits**

When damage is observed in seed beds use a suitable poison bait formula-bran 2.5 parts, sodium fluoride, Paris green or lead arsenate 1/8th part, molasses 1/5th part, water 4 parts by weight mix the dry bran and the poison powder thoroughly in a vessel; dissolve the mollasses solution to the bran mixture and stir so as to make a dryish mass or porridge that is loose or crumbling in the hand; distribute the bait thinly in small quantities broadcast over and near the affected areas, putting it shortly

after sunset just before the cutworms come out to feed at night; about 2 kg. of bait per 100 sq yd of nursery beds is recommended.

(e) **Dust and ashes**

In absence of poisons, one remedy is to dust the seed beds thickly with wood ashos or a mixture of quick lime and ashes. This measure acts more as a physical barrier to the cutworms than as a repellant.

(f) **Trap method**

Succulent leaves and weeds are out and placed in heaps in the affected area. They serve to attract the cutworms and labour can deal this the following day by killing them at the place where they have concentrated.

(g) **Synthetic insecticides (DDT, BHC).**

3. CRICKETS

Together with grasshoppers, cutworms and cockchafters the crickets form the chief pests of seedlings. Winter is passed underground in the nymphal stage, become active in spring and turn in adults in May-June. Female prepares an earthern cell in soil, eggs are laid in cluster, show natural care for 4 weeks till hatching takes place; young crickets after being nursed by the parents (the mother) disperses; later they go deep in soil for hibernation.

CONTROL

(a) If ground is already infested with crickets, then plough deep. Seed beds in nursery may be isolated by (i) planting or battens, 4-5 inches wide, half above and half below ground, or by trenches.

(b) **Trapping**

Sink earthen pots along the beds; half fill the pots with water containing some kerosene oil.

(c) **Flooding**

Pour water into freshly made tunnels or flood the affected nursery and force out the crickets and kill; it is advantageous to add to water weak emulsions or kerosene; Choose sunny days following rain and spot the fresh tunnels quickly.

(d) **Nests**

Destroy in mid-summer eggs and young nymphs by hosing, say as deep as 4 to 6 inches.

(e) **Baiting**

Place half-cut pumpkin on the ground and cover it with weeds etc. overnight; crickets take shelter here and the following morning they can be destroyed. Poison baits can also be laid.

(f) **Direct killing**

Every morning before watering the nursery all the fresh tunnels, spotted by the presence of heap of soil collected at each entrance hole on ground. Should be checked up with finger pushing inside the hole or with a hooked appliance and pull out the live crickets and kill. This should form a daily routine.

(g) **Synthetic insecticides (DDT, BHC)**

4. TERMITES (WHITE ANTS)

Termites are social insects, living in colonies, subterranean in habit and requiring soil moisture and avoiding light throughout their life. In the colony can be found a large number of sub-groups, each performing special duties for the colony, and the commonest of these are king, queen, soldiers and workers; the royal pair king and queen live in a royal mud-cell underground, the workers work for the colony (bring food, construct nest, etc.) and soldiers guard the colony. The

commonest nest of termite visible above ground is the termite-mound, which is spectacular and is only a part of the nest, the main colony being underground. The young termites that hatch out from eggs, called nymphs, are specially fed on fungus that is grown in a fungus garden in special beds called fungus combs. Later they are allowed to graze alongwith other termites and they chiefly consume cellulosic materials as food which no other insect group has the power to digest. This material is obtained through protozoan fauna that grows in the alimentary system of termites. Thus other insects cannot compete with termites in matters of food. Termites have interesting habit of licking each other and can transmit any kind of food, be it their normal food or a poison by accident from one termite to another. Wood in buildings in forests lying on ground, in mils, depots, bark of living trees, young plants and their roots, cloth, papers etc. are eaten by termites.

CONTROL IN NURSERY

(a) Preventive measures

(i) **Seed beds and nurseries** : Site for new nursery etc., should first be cleaned, destroy termite nests either by directly killing the colony or by chemicals. It is necessary to kill the entire colony and not be satisfied with the killing of the queen. Isolate nursery from future invasions of termite by trenching all round. Oil cakes have manural value and also keep off termites. All wooden boards, labels, etc. used in nursery should be treated preferably with creosote under pressure.

(ii) Bamboo baskets can be used for transplants and the baskets should be treated otherwise they will attract termites. Much of the subsequent termite attack on transplants is due to injury to the roots at the time of lifting. Termites first attack the dead roots continue to work on the living tissues when

the resistance of the plant is lowered. Prompt and careful transplanting is the cure.

(iii) **Patch sowing** : Seeds dibbled in small numbers or broadcast on small patches are liable to attack if the soil contains an abundance of leaf and woody litter hence sowings on ash beds are more satisfactory. Stakes that are used to mark patches of sown seeds should be dipped in creosote.

(b) Remedial measures

When young plants are observed to be drying off in seed beds and in nurseries, upper layer of soils should be turned over and searched for termites. The dying may also be due to cockchafters, cutworms, crickets, etc., or to drought or to damping off. If termites are responsible for dying it is best to water the lines with weak crude oil emulsion or concentrated extract of tobacco leaves. Permanent baits of saw dust and pieces of softwoods poisoned with Paris green (100 : 1 of poison) or saturated with a 10% solution of sodium arsenite can be kept in stock and spread in the affected nurseries when desired. Red or black ant nests may be spread on seed beds and they will kill the termites. If suitable termiticides are available they should be used, such as paradichlorobensene (liquid or crystals), arsenious oxide (white arsenic) or Paris green mixed with ash or dust, or synthetic insecticides dusts (DDT, BHC), when the soil is permanently moist.

5. GRASSHAPERS, DEFOLIATORS AND SAPSUCKERS

Defoliators (caterpillars, beetles, grasshoppers) should be handpicked or dusted with poison or baited particularly the grasshoppers. Sapsuckers, cause withering as living sap is drained out of plants by the piercing sucking mouth of insects, need pretreatment with suitable emulsions and synthetic insecticides.

SEED PESTS AND THEIR CONTROL

Successful seed storage depends on (1) correct control of temperature and humidity conditions, (2) on successful protection of the seed from seed-eating insects and animals.

In natural state seeds are the staple food of many kinds of birds, animals and insects and a very high proportion of the seed produced each year is consumed by one or other of these agents.

Seeds placed in storage are also liable to attack and insects are the most dangerous pests of stored seeds. The larvae of various kinds of beetles are particularly troubles-some. Rodents are the most damaging seed pests.

(1) Beetles cause much damage to seeds than any other class of insects; many species of weevils infect the fruits and seeds of trees (particularly seeds of oak, Dipterocarpus and Leguminceae); Eggs laid on young fruits, larvae bore in and pupate therein. Seed beetles of this family are usually pests of growing fruits and seeds which are still on the tree but larvae continue to develop inside seeds that are collected and in storage infect fresh ones by boring out from the infected ones.

(2) Bruchid beetles (seed beetles or pulse beetles) are the principal pests of seeds kept in storage and multiply rapidly from a small initial infectation.

(3) Moths also serious pests of fruits and seeds of trees. In most cases pyralid larvae feed on growing fruits and immature seed example *Hypsipyla robusta* in the seed capsules of toon and mahogony.

(4) Ants and termites cause losses on stored seeds.

(a) **Prevention of insect attack**

(1) Care in collecting and cleaning seed; seeds should be collected as soon as it is ripe. It is difficult to bring moisture content of seed below.

(2) Remove sources of infection from the storage site.

(3) Select a suitable method of storage.

(b) **Protection from rodents (rats, mice squirrels)**

Seed store should be rodent proof, wire netting, traps, poison, baiting (use baits cautiously, risk to domestic animals, unhygenic smell, human beings), cats and dogs.

MAJOR INSECT PESTS OF TREES

(1) **Teak defoliator** : Teak is a very important timber species of India. Its leaves are skeletonized by two insects :

Hapalia machaeralis (Teak skeletonizer)
Hyblaea puera (Teak defoliator)

Life History : These cause the complete or partial defoliation of young teak plants, thus leading to dying back and forking. *Hyblaea* epidemics occur generally in April-May and again in the month of November. *Hapalia* is found to be abundant between April to early June and also in August and September. However, their life cycle may also vary with climatic conditions and availability of alternative; host behaviour of their parasites and predators etc.

The following control measures may be adopted :

Silvicultural :

(a) Large pure teak plantations should not be raised.

(b) Pure teak stands should be separated by strips or zones of natural forests.

(c) These steps may further be strengthened by eradicating the food plants of the pest concerned and also by introducing certain desirable species.

(d) Controlled burning should be avoided.

Biological : The pest may be controlled by release of *Cedria paradoxa*.

Chemical : It is not very economical to use chemicals for the control of these pests as their life cycles are very short and over 15 generations may occur in a year.

2. **Deodar defoliator :** *Cedrus deodara* is another important timber species of India. Its defoliator is *Ectropis deodarae*.

Life Cycle : This pest has an annual life cycle and its moths emerge in March. Epidemics occur at intervals of 2-3 years. Death of he defoliated tree starts from the top first. The bark is in longitudinal patches; and the cambium may also be attacked. Under such conditions trees may become susceptible to attack by other harmful pests.

The following control measures can be taken up :

Silvicultural :

(a) Mixed plantations may be taken up.

(b) Litter removal and overgrazing should be done away with.

Biological :

Calesoma beesoni is an important predator and populations of this pest may be controlled by the release of the

above. This predator eats caterpillar and also devours the larvae (pupae) in the humus.

Mechanical :

(a) Raking of humus during the month of June when the caterpillars crawl under them.

(b) Trees are also grease banded before the month of March so that breeding does not occur.

3. **Shisham Defoliator :** Severe defoliation of *Dalbergia sissoo* is done by *Placoptera reflexa*. This makes the shisham tree leafless for a considerable part of the year thus,

(a) Growth is hampered to a large extent.

(b) Presistent attacks may lead to the death of the tree.

The following forms of control may be adopted :

Silvicultural :

(a) Shisham should only be raised where suitable edaphic and hydrological conditions exist.

(b) Such methods should be adopted that trees produce a flush of young leaves before the caterpillars are hatched. This is because of the fact that caterpillars feed on young and flushy succulent leaves.

(c) Early thinning operations in plantations are also desirable.

Biological :

Biological control entails using many parasites and predators of this pest to control its population.

4. **Toon Shoot borer :** Tun - *Toona ciliata* is attacked by a shoot borer - *Hypsipyla robusta.*

It also attacks trees of Swietenia (Mahogany) and Chukrasia. In case of tun, shoots are also attacked. The first two generations of the pest attack its flowers and fruits. As a result seed production is affected. The third, fourth and fifth generation of the pest attacks shoots of the above trees. Thus growth is checked and young plants die, in the case of serious epidemics. The following modes of control may be undertaken:

Silvicultural :

(a) Only such sites for plantation should be chosen, where no alternative host is available.

(b) In this connection, it must be mentioned that plantations should not be raised in or near mixed forests of tun, mahogany etc.

Mechanical :

(a) **Pruning :** Pruning may be carried out in the case of young trees.

(b) **Sack banding :** A gunny bag may be tied around a tree, at a height of about 80 cms above the ground level. The larvae will take shelter underneath it. They can be collected and destroyed before they spread.

5. **Semal Shoot Borer :** The shoot borer of semal (*Bombax ceiba*) is *Tonica niviferna.*

Life Cycle : The young larva bores the young plant of semal near the leaf axil. It lives inside the shoot by boring a tunnel. The pest may make the shoot completely hollow, thus killing the young tree.

Mechanical Control :

(a) Pupation occurs on the leaves. Thus, the pupae may be collected and physically destroyed during the months of April-May and July-August.

(b) The attacked plants may be cut and the shoot burnt.

6. **Chir Shoot borer :** *Pinus roxburghii* or Chir pine is another important timber species of the country. During its sapling, pole and even older stages, it is attacked by a borer- *Ips longifolia.*

This may be controlled by proper slash disposal and all felled material should be properly debarked.

7. **Sal Heartwood borer :** Sal is another important timber species of India *Hoplocerymbax spinicornis* in the most serious pest of *Shoria robusta* (Sal) in India.

These pests may cause damage to Sal trees in two forms :

(i) The larvae may eat up the cambium and kill the tree.

(ii) The pest bores long galleries both in the sapwood and heartwood, thus lowering to a great extent, the commercial value of the timber and making it weak.

Some controls are as under :

Silviculture :

(a) The crop should be fairly dense.

(b) Felling should be confined between October and March.

Mechanical :

(a) Traps may be used on trees.

(b) Beetles can be attracted by freshly oozing sap and then killed by severing of the head.

CHAPTER 21

FOREST DISEASES

All plants are affected by diseases. The term diseases refers to the abnormal state of an individual. In plants diseases may be described as sustained physiological and resulting structural disturbances of living tissues and organs ending at times in the death of the trees particularly young individuals. A characteristic feature of diseases of trees is that it is a continuous process and not transient and temporary such as caused by injury during the lopping of branches, thinning etc. Thus a disease is different from the symptom or condition of the disease.

SYMPTOMS

Symptoms are apparent expressions of the process of diseases in plants. These may develop some time after a plant gets infected with the period being known as the incubation period. Every disease appears in the form of one or a combination of more symptoms. These may be of two main types:

a) Systemic; in which the entire plant exhibits symptoms of the disease and

b) Localised; where the symptoms are restricted to the particular parts of the plant which have been affected.

Disease symptoms may be of the following three classes viz necrotic, atrophic and hypertrophic. These have been described in brief below:

1. **Necrotic symptoms**:

Necrosis is a term used to denote the death of affected tissues. It may occur in green leaves during the early stages of an attack as a result of which there is change in colour to yellow or brown or red and finally resulting in the death of the leaves. The entire organ may be killed as in leaf blight and bud blight or a

portion of the leaf is affected as in the case of leaf spots or shot holes.

Necrotic symptoms are further of the following types:

(a) Pathological wilt caused by attack by a root or stem fungus causing permanent irreversible wilt in plants.

(b) Cankers are localised lesions on woody stems formed due to the killing of the bark tissues or cambium usually leading to open wounds exposing the wood from beneath. Cankers with stratified margins develop if the cambium is repeatedly killed due to frequent callusing.

(c) Decay is a term given to the breakdown of the tissues. Decay fungi may occur in the dead heart wood of trees thereby causing heart rots.

2. **Atrophic or Hypotrophic symptoms :**

These symptoms develop due to the slowing down in the development of the plants or their parts as a result of subnormal cell division or from the degeneration of the cells. Dwarfing is the common symptom in such cases.

3. **Hypertrophic symptoms :**

These symptoms develop due to overgrowth brought about by an abnormal increase in the number of cells.

SIGNS

Signs depict the diseased condition of the tree. These include vegetative or fruiting structures of the disease causing organisms which usually develop at or near the points of infection and also different types of exudations. Trees that have been attacked by heart rot fungi usually do not show any external

symptoms but depict certain signs with the help of which it is possible to know about the disease.

(1) **Fruiting bodies** : These are vegetative or reproductive structures of the organism causing the disease. The fruiting structure or sporophores or fruitifications of fungi commonly develop on diseased plants and are important signs of the diseased condition of the tree.

(2) **Epicormic branches** : Trees growing under adverse conditions have a limited development of branches in clusters on the main stem due to the activity of the dormant or adventitious buds. These are known as epicormic branches that form due to infections, insect attack or non-infectious causes.

(3) **Exudations** : These may occur as a result of the normal physiological processes in the trees or plant. Guttation is a type of exudation in which water is forced upon uninjured free surface of the leaves. However other forms of exudations may be caused by bacteria or non-infectious causes as in the case of water blister in teak.

GENERAL PRINCIPLES OF FOREST DISEASE PREVENTION AND CONTROL

The main object of forest pathology is to keep forests free from diseases. In the event of outbreak of diseases the aim should be to minimise the damage and to prevent it from spreading. Control of forest diseases may be done by direct measures such as sanitation, eradication, isolation trenches and chemical control and indirect measures such as choice and improvement of site, choice of species, resistance breeding and biological control.

The general principles of forest disease control have been discussed in the following text:

1. **Sanitation :**

The process of sanitation reduces or eliminates the initial inoculum from which the disease develops. Sanitation measures include-

- removal of diseased trees as soon as possible. These are known as sanitation fellings.

- removal of fruiting bodies of fungi in order to reduce the disease inoculum.

2. **Eradication:**

Eradication of one or more than one hosts helps to prevent and control the occurrence of disease in forest areas. Heteroecious rusts need two hosts for completing their life cycles. Eradication of one of the hosts helps to control the disease. The alternate host may be a weed or a valuable species which has to be eradicated in favour of the more valuable crop.

Residual stumps may also act as hosts. Their removal prior to planting helps to prevent and control the occurrence of root rot.

3. **Isolation trenches:**

After a root disease establishes itself in a forest it tends to spread centrifugally from the centre of the infection to the adjacent trees. The diseased plants can be isolatedby digging isolation trenches around them.

4. **Chemical control:**

This is an expensive method of controlling forest disease which can be applied only in the case of nurseries and plantations. As the name suggests chemicals are made use of to control the various diseases. Fungicidal chemicals help to both

prevent the occurrence of the disease and also to control the infection once it has set in.

The timimng and method of application varies from case to case.

5. **Choice and improvement of site:**

This is another effective way of controlling forest diseases. Natural stands are adapted to the site occupied by them. Thus natural forests tend to remain healthy as long as they are managed on scientific lines. However in the case of plantations suitable selection of site and its improvement if required is imporatnt particularly for exotics which are far removed from their natural range or home. The site may have to be improved if it is not suitable. This prevents the occurrence of diseases.

6. **Choice of species :**

A characterstic feature of natural forests is slow growth and low productivity. This proves to be a blessing in disguise so far as forest disease control is concerned. Further more such forests have a natural mix of species which acts as a barrier against the incidence of diseases.

However the right choice of species has to be maintained in plantations if they are to be effectively protected against diseases. From management and commercial point of view a pure crop is preferred but pure plantaions may not be suitable for protection against diseases. Suitable choice of species is thus important from this angle.

NURSERY DISEASES

In the recent past, thre has come about an ever increasing role of nurseries in the regeneration of forests and also in raising trees on hitherto barren lands. During the last decade a large number of aforestation projects have come up. Such large scale plantation projects have necessitated the

setting up of more and more nurseries for raising planting stock. The propagation of many social forestry species from seed is not only difficult, but also involves a fair degree of technical knowledge. Nursery management has thus become a very important aspect of forestry. It is essential that high quality planting stock is available at as low a price as possible.

Damping off is the main disease affecting seedlings in a nursery. Seedlings are attacked at their base near ground level by fungi belonging to Phytophthora; Pythium, Rhizotonia and Fusarium which are usually found in the soil. Due to fungus attack; rotting starts at the base of the seedlings and they may suddenly faff on to the ground.

The following measures are adopted for controlling damping off and other nursery diseases :

1. **Soil condition** : Various diseases may be kept at a low level by going in for light textured; well drained acidic soils. In case the soil is near neutral or alkaline, it may be acidified by any of the following :

(a) concentrated sulphuric acid (100 to 400 ml in 4.5 lts water)

(b) sulphur (250 50 to 300 gms flowers of sulphur)

(c) aluminium sulphate (powdered, iron free; 17 to 18% Al_2O_3 at 340 to 680 g)

(d) ammonium sulphate fertilizer

The exact dosage of the chemical to be applied will depend on the buffering capacity of the soil. However, if the soil contains a high content of calcium carbonate; acidification will not have a lasting effect. In this case the soil drainage condition will have to be improved, in addition to introducing some other measures; as suggested in teh points mentioned below.

2. **Steaming** : This is a process in which steam is passed through the nursery soil. As a result, of the high temperature at which steam is passed the soil pathogens are killed.

Steaming is a costly, cumbersome and lengthy process. There are two methods for steaming the soil :

(a) soil may be put under running steam at an autoclave or closed container for an hour or so.

(b) in seed beds, pipes with perforations may be led into the beds which are covered with gunny bags. Steam is let into these pipes for an hour or so in each bed.

3. **Chemicals** : A number of chemicals are used for treatment of the nursery soil against diseases. These may be :

(a) Formalin is applied to the beds 10 to 15 days in advance of sowing so that during this period the toxic effects are removed through volatilization. Commerical grade formalin (38% formaldehyle) is diluted in water (250 m in 4 lts water) and is applied as soil drench per square meter of bed.

(b) Methyl bromide is another highly phytotoxic chemical which has to be applied 10 to 15 days in advance of sowing. Ampules of methyl bromide are broken under a thick polythene sheet spread over the nursery bed with its edges burried in the soil. Vapours thus released will slowly diffuse into the soil. Methyl bromide is highly toxic and it also kills weeds, nematodes and insects whcih may be present in the soil.

(c) Other chemicals which are used include :

Brassicol : 22.5 g of a 75.0% dust of pentachloronitro benzene.

Blitox : 19.3 g of a 50.0% dust or copper oxychloride.

Captan : 20.5 g of a 83.0% dust of N-trichloromethyl mercapto -4- cyclohexene -1, 2 dicarboximide.

Cuman : 22.5 g of a 80.0% dust of zinc dimethyl dithiocarbomate.

Thiride : 22.5 g of a 75.0% dust of thetramethyl thiuram disulphide.

Zinc Oxide : 17.0 g of a 100.0% dust of zinc oxide.

Zineb : 26.0 g of a 65.0% dust of zinc ethylenebisdithiocarbamate.

4. **Fungicidal seed treatment :** This involves the use of chemicals like cumam, thiride, blitox etc. for the control of fungus in the soil. Fungicidal seed treatment brings about effective control of damping-off and also seed-borne disease in case of a number of broad leaved species.

ROOT DISEASES

The root system of a tree may suffer from serious diseases; symptoms remaining unnoticed before they begin to appear. These disease may be due to parasites like fungi constitute an important group of organisms causing root diseases in forest trees.

ROOT INFECTING FUNGI

The root infecting fungi comprise an ecological group which is distinct from other parasitic fungi in a way that the former involves a triple biological relationship with the host plant; the parasite and the general soil micro-flora under different conditions of soil structure; soil moisture; soil reaction; soil

nutrients. The soil contains a number of microorganisms residing in it e.g. fungi, bacteria, actinomycetes, nematodes, protozoa, insects etc. These are in a state of constant equilibrium with the soil. root infection fungi living in the soil may atack roots of trees to cause diseases.

Waksman (1917) has introduced two terms in this context :

Soil inhabitants : those micro organisms which reside in the soil.

Soil invaders : those micro organisms which come in from outside.

Garrett (1960) has used the terms "soil inhabiting fungi and root inhabiting fungi. He has described root inhabiting fungi as possessing; an expanding parasitic phase on the living host, and declining saprophytic phase after its death".

Saprophytic Phase : This phase of life of parasites depends upon their ability to colonise various substrates and also their capacity for competitive colonisation of substrates in the presence of other micro-organisms. Two types of saprophytic behaviour is seen in case of root inhabiting fungi - saprophytic survival and saprophytic colonisation. Saprophytic survival phase is very prominent in the following :

Fomes annosus	*F. lignosus*
Ganoderma lucidum	*Armillaria mellea*

PARASITIC PHASE

I. **Pathogenic soil inhabiting fungi** : There is a basic difference in the parasitic behaviours of the fungi of soil inhabiting and root inhabiting groups.

Garett (1960) has given the following possible evolutionary sequence for soil inhabiting parasites :

(a) primitive parasites that destroy seedlings and young tissues of a wide range of hosts but are resisted by nature tissues of the host e.g. damping off fungi.

(b) less primitive parasites that are less restricted by effective resistance offered by the host.

(c) specialised parasites which attach the host tissue and do not show any other saprophytic activity besides passive survival in tissues invaded by them as parasites.

(d) parasites whose relation with the host is symbiotic e.g. mycorrhiza. This evolutionary sequence does not necessarily mean that an inverse relationship exists between parasitic specialisation and saprophytic ability.

Fungi which cause vascular wilts limit themselves in that particular vascular tract, where they survive and multiply. these fungi lead a semi-saprophytic existence and hence are primitive in comparision to the root rot fungi. Vascular fungi do not emerge from the vascular cylinders, till a fairly advanced state e.g. in case of *Fusarium* and *Verticillium.*

II. **Vascular wilts** : Soil inhabiting fungi which cause vascular wilts, belong to the group of primitive parasites; they enter the host through young roots and rootlets; then limit themselves to the vascular tract, where they multiply and survive. Living cells surrounding the vascular tracts are not attacked by them, till death of the host. Water conductivity of the conducting tissues is severely affected by this pathogen.

Wilting of the foliage of the entire individual may occur in wilt disease. Examples of wilt causing pathogens are *Fusarium oxysporum, Verticillium.*

III. **Root rots** : Root rot fungi are a group of a pathogenic root inhabiting fungi. Infection starts from the root and its further spread depends upon the resistence offered by the host. However, the symptoms of root attack do not become evident, till a large part of the root has been affected. Some examples are :

1. **Root rot** - *Ganoderma lucidum*
2. **Root and butt rot** - *Fomes annosus, Polyporus schweinitzii.*
3. **Stump rot** - *Fomes lignosus.*
4. **General root rots** - *Armillaria mellea, Peniphora rihizomor - pho sulphurea.*

CONTROL

There are a number of ways in which root diseases can be controlled. Generaly, it is more difficult to control this disease, because the underground plant parts are not easily ascessible. In case of disease of aerial parts, it is possible to spray fungicides etc. However, control of root disease by use of chemicals, will not be very successful, even if chemicals are added to the soil. Any soil fumigant which is applied to destroy the ecototrophic growth of root inhabiting fungi, may be harmful for the host also. Soil fumigation may be brought about by methyl bromide and steam; under glass house conditions, before sowing, for the control of damping off and other root diseases. However, soil fumigation canot be carried out in forests on a large scale.

Crop rotation is a fairly popular and effective method for the control of root diseases in agricultural crops. As a result of crop rotation, the availability of host becomes very restricted. However, this method is not suited for forestry crops due to the exceptionally long period of rotation.

Certain options available for control of root disease in case of forest crops are :

(a) propogation of resistant species.

(b) raising of mixed plantations.

(c) adopting measures to quarantine the host and disease.

Control by silviculture and management : Silvicultural and management methods are used to control root diseases in forest crops. These may be :

1. **Site selection** : It is essential to have an indepth knowledge of silviculture, for deciding which species is to be raised under what conditions. Take for example the case of sisham. It is not advisable to raised sisham on stiff clayey soils or under conditions of water logging as this will tend to make the trees prone to attack by root infecting fungus. Thus, it is imperative to have an indepth knowledge of the action of root growth of a particular species on the site conditions.

2. **Control burning** : In case of certain species, control burning helps to keep down root diseases. Take the example of wet sal. Control burning during late winter helps to protect wet sal from attack by *Polyporus shorae*. Besides control burning also helps to :

- keep down fire hazards
- reduce root competition.

3. **Mixed stands and resistant species** : In certain areas, it may be advisable to raise mixed stands or plantations so as to reduce root diseases. In a natural forest, species prone to attack by a particular root disease may have to be removed. This will bring about a reduction in host availability. Resistant species are those which have a certain degree of resistance to a particular species. Such species may be introduced in the forest to check the spread of rot disease of a particular type.

4. **Site preparation** : In India, we are going in for large scale plantations. The following steps during site preparation, will help to keep down root diseases :

- removal of residual roots and stumps from the entire area with simultaneous soil working wherever possible. However, root resisuals lying deep in the soil may not be removed.
- roots of resistant species may be retained in the area.
- in cases where it is not possible to remove root residuals, some form of soil working is essential to keep down incidence of disease.

5. **Isolation trenches** : Root disease spread from root of one tree to another. Usually, this is by contact; migration of pathogens or by root grafts resulting in diseased plants occurring in groups. Isolation trenches are dug up with a view to isolate the roots which have already been infected by the disease. The disease or pathogen is contained within the trenches thereby preventing it from spreading to other areas.

Other silviculatural and management practices include :

- delayed thinning for the control *Fomes annosus.*
- adjusting time to thinning during a period when temperature at the stumps surface reaches levels lethal for certain pathogens.

Chemical control : Spread of root diseases may be controlld by the use of fungi. An ideal stump treatment needs to be able to prevent not only infection at stump surface, but also in killing the stumps rapidly, so that pathogens do not get a chance to survive and multiply. further, the chemical usewd should be easily available; be easy to apply; also shold not have any side effects and should be nonpoisonous to wild animals and humans. Amongst tested and recommended chemicals are ; ammonium

flouride, sodium nitrite, borax, urea, creosote, ammonium sulphamate etc.

Biological control : The biological control of soil borne pathogens has not been very encouraging; as success depends upon complex interactions in a medium which is colonised by a large number of microorganisms. On the other hand, in case of wood inhabiting pathogens, control is easier, as they colonise wood tissues which are virgin substrates and also are relatively more selective. One example of chemicals control is of *P. gigantea* which may be inoculated for the control of Formes annosus.

HEART ROTS

Heart rots are one of the most common tree diseases. Decay does not set in till heartwood is formed; this may be during the 15th to 30th year of growth. Central core of the dead heartwood is insulated against attack by decay fungi by the outer living sapwood and the bark. However, a stage comes when the heartwood is exposed through openings in the bark and sapwood, thus, giving rise to heart rot which becomes progressive with time. Decay affects only the heartwood, which is dead; the living wood remains unaffected, thus, trees are not usually killed.

Decay fungi : There are a large number of fungi which cause decay in the heartwood of standing trees. Most of these fungi belong to the Hymenomycetes of which the genera Polyporoceae is the most important. Detailed list of decay fungi belonging to this genera, which attack Indian tres have been published by Bakshi (1964, 1971) Sporophores help in the identification of these fungi; and in their absence, they may also used for identification purposes and may be determined in culture from chemical tests.

INFECTION AND ESTABLISHMENT : Tree wounds usually lead to trunk and basal rots. In case of root and butt rots, pathogens enter through either of these two regions and spread

from one into the other. The following factors determine the establishment of fungi.

1. **Moisture** : High moisture in the sapwood prevents heart rot fungi from progressing into the sapwood. Moisture in heartwood is such that fungi are able to establish and multiply.

2. **Temperature** : Optimum temperatures for growth of decay fungi in hewartwood are approxomately the same as those for algae.

3. **Nutrients** : Chemical changes bring about the formation of certain substances, which can afford protection against invading microorganisms. The availability of nutrients has a bearing on the progress of the decay.

4. **Fungi** : Primary colonies may produce suitable nutrients for further colonization by other microorganisms or decay fungi.

5. **Natural extractives** : Toxic natural extractives produce a certain degree of resistance to decay fungi. These are usually formed during developoment of the heartwood and are usually deposited in the cell wall. Most of these extractives are phenols, their chemical nature varying from species to species. Some examples of these extractives are thujaplicin in some conifers; tectol in teak; lepachonon in broad leaved species and coumarins and phenols in many other species.

PROGRESS OF DECAY IN STANDS :

The following factors have a bearing on the progress of decay fungi in forest stands :

1. **Age** : The tree becomes prone to attack by heart rot with age; as heartwood develops only after a certain age. Infection depends on the age at which causes of infection develop i.e. fire, frost, wounds etc. In sal, frost may result in the formation of cankers through which *Fomes caryophyll* may enter into the heartwood. The magnitude of heartwood decay in a forest stand

increases with age. Decay will be very high in overmature stands, where no new wood is being added.

2. **Site condition** : Site conditions do not have a direct bearing on decay in forest stands. However, site indirectly affects the incidence of infection by bringing about an increase in the period of susceptibility, through a prolonged persistence of infection on the tree e.g. slow healing of wounds and branch stubs on less vigorous trees under poor site conditions.

Thus there is an increase in the decay volume percent of forest stands under poor site conditions. In a god site, even though the decay volume percent is fairly high, it is off set by the higher productivity at such sites.

3. **Soil texture** : Soil texture has a bearing on the incidence of rot in heartwood. In case of *Picea,* there is more decay on clayey soil, and less on sandy soil and vice versa in case of *Larix* (as shown by Peace 1938). Populus stands are less prone to heart rots over sandy silt or loam than on impervious soil.

4. **Soil moisture** : Soil moisture is another factor which has bearing on the volume percent of heart rot decay in forest stands. Dry sites are more suited for the development of heartwoods; than moist sites.

5. **Soil reaction** : Certain instances of the effect of soil reaction on the progress of heart rot are :

- infection of *F. annosus* in *Pinus elliotii* increases with an increase in the pH of the soil.

- infection of *F. annosus* in Picea is more in areas of higher pH.

6. **Stand vigour** : In the same age class, stand vigour has a major bearing on volume percent of decay. Incidence of infection may not be largely affected by stand vigour; but poor growing conditions, do bring about an increase in establishment and multiplication of the decay fungi.

DETECTION OF HEART ROTS

Heart rots cause progressive decay; hence they result in progressive increase in the decay volume of the tree and stand. Further, diseased trees are a source of infection to healthy trees. Thus, it is clear that early detection of heart rot is a must. The following features are used for the detection of heart rot :

1. **Sporophores** : Presence of sporophores of heart rot fungi on a tree is a clear indication of the presence of the disease. Certain fungi have the tendency to develop abundant sporophores, soon after their establishment in the heart wood; whereas this process is slower in case of other species.

2. **Swollen knots** : A knot is formed when the position of the base of a branch becomes embedded in the wood during growth. When the living wood tries to grow over a knot in which a sporophore is present, a swollen knot results.

3. **Punk knots** : These are cylindrical cores of soft, punky tissue of the wood which has been decayed by fungi, embedded in the sapwood upto varying depths. Punk knots open up on the bark as hard, round or oval structures.

4. **Swollen boles** : In cases where the tree is in an advanced stage or decay, there appears a swelling on the bole in the region of decay. Swollen boles are fairly reliable indicators of heart rot decay.

5. **External injuries** : Openings, scars and wounds also serve as indicators of heart rot disease. Amongst these are included broken tops; basal and trunk scars, injuries due to logging, fire, frost, lightening etc.

6. **Direct methods** : Heart rots may also be detected by certain direct methods such as increment borings, hammering the tree for detection in distortion of sound etc.

CONTROL

Measures for control of heart rot include :

(a) Fire is an important factor which leads to heart rot. Measures for fire control such as control burning should be adopted to exercise control on heart rot incidence.

(b) In localities which are prone to frost, the canopy can be managed in a way that there is adequate protection to the frost tender species.

(c) Thinning and improvement fellings involving the removal of deseased and injured trees may be carried out.

PATHOLOGICAL PROBLEMS IN SOCIAL FORESTRY

Urban Forests :

With an increase in environmental awareness amongst people all over the world, there is an emerging need for urban forestry. Forests raised in urban areas comprise of roadside, industrial shelter belts etc. Areation and water supply to roots is rather limited in such areas, due to buildings, pavements and other obstructions. As a result, the trees are highly prone to diseases. Furthermore, in heavily industralized areas, trees may also be damaged by various forms of pollution - mainly air pollution. construction work may lead to the mechanical damage of trees.

AVENUES

Avenues are raised along road side, canal banks and railway lines in urban, semi-urban and rural areas. Trees are damaged by the following :

1. Numbering of avenue trees by blazing may lead to the development of open wounds. This exposes the inner layers to attack by decay fungi liek *Fomes senex, Ganoderma applanatum.*

2. As trees grow, their lower branches may be lopped to obtain a clear view. Lopping causes exposures in the stem which serve as conduits for disease.

3. Mechanical damage may be caused to the trees with the passage of vehicles, carts etc.

4. Very often, roots of trees along road sides may be exposed by borrow pits. This leaves the root open to attack by decay fungi.

5. Avenue trees along railway tracks may become diseased due to the heat and dust generated from passing locomoties. The inbuilt resistance of trees in such areas, is liable to be disturbed, thereby making them prone to attack by decay fungi.

FARM FORESTRY

Trees provide fuel, fruit, fodder, food and a large variety of monor forest produce to be local people. On maturity, trees may be felled for timber, usually for local use. pathological problems in farm forests may be of the following types :

1. Grazing brings about a disturbance in the growth vigour of the stand; making the trees prone to disease.

2. Lopping of trees causes injury to the stem. These injuries or wounds serve as condits for decay fungi.

3. During fodder collection, a large number of trees may be lopped; leaving the trees barren and prone to disease.

PHYSIOLOGICAL DISORDERS

Disease due to non parasitic or of physiological origin do not normally cause immense damage to forests. However, the

loss may be lopped; leaving the trees barren and prone to disease.

FIRE :

Fire is a common occurence in Indian forests. fire may result in the following damage to the forest crop :

1. Young plantations of fire tender species like *Eucalyptus* may be completely destroyed by the fire.

2. Intense fire may kill the bark and cambium of even mature trees thereby leading to their ultimate death. Wounds are exposed to attack by decay fungi.

3. Underground fires keep on raging below the ground level, thereby leading to the ultimate death of species like Deodar and Oaks. The roots become prone to attack by decay fungi.

4. A large crown fire is likely to destroy all trees coming in its path.

5. Fires tend to make the trees unsound.

SUN SCORCH :

Under conditions of intense isolation, the surface of the stem receiving direct sunlight may attain a temperature more than that of the surrounding air. This will lead to the appearance of wounds on the tree surface, which act as conduits for the spread of decay fungi. Sun scorch is always found on the sunny side.

Open wounds have been seen to develop on fringe trees in even aged teak plantations, near ground level upto a height of 4 to 5 mts.

SOIL MOISTURE :

The following physiological disorders may occur due to low or high soil moisture conditions :

1. Under conditions of low soil moisture, there is likelyhood that young plants may shrivell up and die. Conditions of low soil moisture results from physical conditions of the soil; trampling of the forest floor by grazing animals; low water table; low precipitation etc.

2. Under conditions of high soil moisture, there is poor areation, due to which certain serial parts of the tree may die off; or in extreme cases, death of the tree may occur.

FROST :

Frost causes injury to the cambium. Even though the injury may not be severe enough to kill the cambium; undifferentiated parenchyma may form in place of narmal wood tissues accompanied with the formation of frost rings.

SEED PATHOLOGY

Plants are propogated by seed, which may be a carrier a variety of pathogens. Seeds may also become infected during storage. Seed borne infections show different symptoms, depending upon the nature of pathogens; growing conditions, internal resistance etc. In cases where the embryo is very severely affected, the seed is unlikely to germinate.

SEED AS CARRIERS OF PATHOGENS :

Pathogens may be carried within or on the seed; on the fruit; on cones; on inert material like chaff, straw etc. However, the presence of a pathogen on the seed does not necessarily mean that it is harmful or that it will spread to other parts of the tree or forest stand. Certain seed infecting pathogens are :

1. *Ciboria* causing sclerotina disease on seeds of older, birch etc.

2. *Ceratocystis fagacearum* on oaks and chestnuts.

3. *Xanthomonas fuglandis* on walnut.

4. *Laphodermium pinastri* on pines prunus etc.

Testing of seed health :

Seed health testing involves the examination of a selected number of seeds along the following lines :

- seed reproduceability.
- pathogens carried by the seed.
- blotter test - observing growth of seeds and pathogens simultaneously. Testing of seed health in important for the reasons :

  1. Useful for determining the necessity or otherwise of suitable seed treatment for control of seed-borne pathogens.
  2. It may be used to supplement germination test.
  3. To detect seed borne pathogens which otherwise may spread to other parts of the stand and cause widespread damage.

Seed treatment :

Different methods of treatment of seeds against pathogens include :

1. Dressing the seed with certain protectant chemicals; acts as a spot treatment of the soil around the seed. This method is also used for the control of pre-emergence damping off in conifers.
2. Seed disinfection with the help of certain organic chemicals.

REFERENCES

Anonymous. 1987. India's forests, Ministry of Environment and Forests, New Delhi.

Bakshi, S. 1964. Forest Pathology, Government of India, Delhi.

Champion, H.G. and Seth, S.K. 1968. A revised survey of the forest types of India, Government of India Publication, Delhi.

Khanna, L.S. 1982. Forest Protection, Khanna Bandhu, Dehra Dun.

Negi, S.S. 1986. A handbook of forestry, International Book Distributors, Dehra Dun.

Schlich, W. 1922. Manual of Forestry, Agnew, London.

Tewari, D.N. 1992. Tropical Forestry in India, International Book Distributors, Dehra Dun